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NASA/MSFC FY-81 Atmospheric Processes Research Review

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Summary of a Program Review held in
Huntsville, Alabama
September 1-3, 1981

NASA

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NASA/MSFC FY-81 Atmospheric Processes Research Review

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Summary of a Program Review held in
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ACKNOWLEDGMENTS

The productive inputs and comments from the participants and attendees in the Atmospheric Processes Research Review contributed very much to the success of the review. The opportunity provided for everyone to become better acquainted with the work of other investigators and to see how the research relates to the overall objective of NASA's Atmospheric Processes Research Program was an important aspect of the review. Appreciation is expressed to all those who participated in the review. The organizers trust that participation will provide each with a better frame of reference from which to proceed with the next year's research activities.

PREFACE

Each year NASA supports research in various disciplinary program areas. The coordination and exchange of information among those sponsored by NASA to conduct research studies are important elements of the program. The NASA Office of Space and Terrestrial Applications, via an Application Notice (AN), has invited interested investigators throughout the country to communicate their research ideas for the topics identified in the AN. The proposals in the Atmospheric Processes Research area selected and assigned to the NASA Marshall Space Flight Center's (MSFC's) Atmospheric Sciences Division for technical monitorship, together with the research efforts included in the FY-81 MSFC Research and Technology Operating Plan (RTOP), were the source of principal focus for the participants in the NASA/MSFC FY-81 Atmospheric Processes Research Review held September 1-3, 1981, in Huntsville, Alabama.

The principal purpose of the review was to provide those having major research activities sponsored by NASA's Atmospheric Processes Research Program and assigned to MSFC's Atmospheric Sciences Division an opportunity to meet and discuss their programs and future plans. In addition, the review provided NASA Headquarters and MSFC Research Program Managers with a current status report plus suggestions for future research for use in developing program needs. The principal managers involved were: Dr. Shelby Tilford, Atmospheric Processes Research Program and Upper Atmosphere Research Program; Dr. James Dodge, Severe Storms and Local Weather Research Program; Mr. John Theon, Global Weather Research Program; and Dr. William W. Vaughan, MSFC Atmospheric Processes Research Program. Dr. Robert Turner served as the coordinator for the research review.

Three general areas of NASA's Atmospheric Processes Research Program were included in the review: Global Weather, Upper Atmosphere, and Severe Storms and Local Weather. The final titles of the individual presentations varied depending on the particular emphasis of the designated speaker. The technical aspects of the research efforts were stressed and the individual presentations were developed to provide the rationale for recommendations on the coming year's research. The agenda for the review is included as an Appendix to this report.

There were many research topics to cover, and it was important that each person discipline his presentation time. While the time available did not permit all research topics to be covered, the majority were accommodated during the 3-day review. The organizers endeavored to make the review just that—a review of the major aspects of the sponsored research activities relative to the NASA program aims. The review was planned to be informal to permit the maximum exchange of information among the participants, insofar as practical; and a research team spirit did prevail and was further enhanced by discussions. To provide for a follow-up by the various participants and attendees, each investigator was requested to prepare a brief narrative

outline of his research project. The investigators' unedited outlines are assembled in this report.

It was recognized that the scopes of individual research efforts comprise a wide range. Some are very modest or have been under way for only a short period of time, whereas others involve several years of activity. However, the opportunity to learn what each investigator is doing and to develop the team relationship necessary for a meaningful research program were considered most important. In this context, it is appropriate to restate the aim of NASA's Office of Space and Terrestrial Applications research program; it is toward this aim that all research sponsored by the program should be directed. It is summarized as follows:

> The aim of the research program of NASA's Office of Space and Terrestrial Applications is to establish useful applications of space techniques/technology to improve conditions here on Earth. This aim is pursued through partnership efforts with responsible mission agencies and private entities. In order to establish useful applications and develop additional techniques and capabilities, research is conducted within NASA and with other Government agencies, academic institutions, and private organizations. NASA approaches the specific near-term objectives through its discipline programs (which include Atmospheric Processes).

Recipients of this report on the NASA/MSFC FY82 Atmospheric Processes Research Review are encouraged to communicate directly with the respective principal investigators regarding any scientific and technical matters or questions they might have on the research efforts. Any recommendations or suggestions concerning the program will be welcomed.

William W. Vaughan, Chief
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SECTION I. UPPER ATMOSPHERIC RESEARCH

The NASA program of Upper Atmospheric Research, developed under the Congressional mandates in the FY 1976 NASA Authorization Act and the Clean Air Act Amendments of 1977, is a comprehensive program of research, technology and monitoring. It is aimed at expanding the scientific understanding of the earth's stratosphere and mesosphere and at developing the ability to assess potential threats to the upper atmosphere.

Shelby Tilford

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TITLE: POLYATOMIC MOLECULE DECOMPOSITION IN THE STRATOSPHERE DURING A GEOMAGNETIC STORM

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SIGNIFICANT ACCOMPLISHMENTS FY 81:

Some successful case studies were completed on the stratospheric temperature responses to a solar proton event and a geomagnetic storm. In the geomagnetic storm case, the temperature response was observed at the tropopause level in some auroral zone regions.

In GASP observations that were made by chance during a geomagnetic storm time, a temperature decrease, a CO concentration increase, and an O_3 concentration decrease occurred simultaneously in the lower stratosphere in the polar regions.

Radioactive cooling due to polyatomic molecule decomposition in the upper layers is proposed as a possible mechanism. The decomposition is hypothesized to be caused by the bombardment of slow secondary electrons that were produced by the auroral X-rays. A feasible logic is developed.

Auroral X-ray transfers were calculated taking the compton softened component into account. It was found that because of the slow decay rate during transmission large enough concentrations of auroral X-rays remained below 20 km to produce the GASP observations results.

CURRENT FOCUS OF RESEARCH WORK:

Observational confirmation of the polyatomic molecule decomposition during geomagnetic storm is the current concern. Measurements of CO_2, H_2O, and O_3 and temperature by airplane are the main requirements.

PLANS FOR FY 82:

Recommendations for New Research:

(1) Estimations of both the magnitude and extent of the magnetic storm effect on temperature.
(2) Estimations of the influence of the temperature modification on the general circulation.

LIST OF PUBLICATIONS PREPARED SINCE JUNE 1980:

Sekihara, K. Polyatomic Molecule Decomposition in the Stratosphere During Geomagnetic Storms. (Presented at AGU Spring meeting May 26, 1981, Baltimore, and to be submitted to J. Geophys. Research)

TITLE: ATMOSPHERIC EMISSIONS PHOTOMETRIC IMAGER ON SPACELAB

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SIGNIFICANT ACCOMPLISHMENTS FY-80:

The Imager was proposed and accepted as a Spacelab 1 experiment. Several experiments have been proposed for future missions and those have been accepted for definition. The Imager as configured for Spacelab 1 has two optical channels. The TV channel has a selectable 6° or 20° FOV and uses an image intensifier in series with an SEC vidicon television tube. This channel is sequenced by a dedicated computer so sensitivity and signal to noise can be optimized for the scientific objectives. The second channel includes a 10 x 10 -channel photon counting array which is bore sighted with the higher resolution TV. The instrument includes its own pointing system and experiment developed software for optimum experiment control. The responsible institutions include LMSC for the optical system and MSFC for the pointing system, computer, software, and environmental test.

This past year's activity was focused on fabrication and verification of the flight hardware and software systems. Several design and fabrication impacts have risen from launch load increases and safety rule changes which impact pointing experiments.

In February, MSFC hosted a 'AEPI reflight' investigators meeting to collect the experimental requirements of the 'Future' spacelab AEPI team. Reflight objectives, including a broad range of thermospheric, mesospheric, and tropospheric emission sensing, were presented by each Co-Investigator attending. Reflight planning has ceased at least temporarily due to budget changes in the Spring of 1981.

We gave considerable attention to image detection devices which would replace the SEC image tube on reflight. We temporarily postponed an effort aimed at upgrading the 10 x 10 diode array to a high resolution imager in favor of existing devices. Currently attention is being given to proximity focused image intensifiers mated to available CCD and CID solid state imagers.

CURRENT FOCUS:

1. Continue to test experiment hardware for delivery to integration in January, 1981.

2. Train the flight crew on experiment operations and associated data interpretation for the Spacelab 1 mission.

3. Develop ground operation hardware and software for Spacelab 1.

4. Experiment with technological improvements in low light level images on ground and balloon borne scientific applications.

PLANS FOR FY-81:

1. Continue 1 & 2 above until delivery to integration.

2. Spend considerable time on POCC activity.

3. Mature future mission plans.

4. Experiment with imaging devices and image processing.

RECOMMENDATIONS FOR NEW RESEARCH:

Pursue detector development for Satellite application to faint source atmospheric emissions in UV-VIS-near IR wavelengths.

PUBLICATIONS

Sandie, W. G., S. B. Mende, G. R. Swenson, M. E. Polites, "Atmospheric Emissions Photometric Imager Experiment (AEPI) for Spacelab 1," Proceeding of SPIE conference, Feb. 9-13, Los Angeles, 265-38.

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SECTION II. GLOBAL WEATHER RESEARCH

The NASA program of Global Weather Research is to develop an improved capability for making global observations of meteorologically important parameters in order to increase the understanding of the complex processes which influence the large-scale behavior of the atmosphere.

John Theon

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THE OBSERVED STRUCTURE OF GLOBAL WEATHER PHENOMENA --

PROSPECTS FOR PREDICTION BASED ON SATELLITE DATA

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Goals of the Research

The goal of our research at Penn State is to combine the observational capabilities of satellite systems with dynamical knowledge and principles to obtain an enhanced capability for understanding and predicting the structure and evolution of global weather phenomena.

Initial research efforts have been directed at identification of cyclic phenomena, such as the zonal index cycle, and the determination of concomitant interactions between the motion and heating fields. These studies have pointed the way to modeling efforts (described in an accompanying report) aimed at determining precisely how transitions are controlled and to development of a conceptual approach for predicting evolution of long-wave structure using satellite data. They also point to some potentially fruitful investigations for the AGCE effort.

Significant Accomplishments and Current Focus of Research

The efforts of the last year have been devoted to study of empirical relations between global scale cyclic phenomena using both conventional and satellite data and to development of the outline of a prediction scheme for large-scale global phenomena.

We have focused our efforts on phenomena associated with the winter-time cyclic behavior of the strength of the zonal component of the westerlies (the zonal index cycle). There are three distinguishable oscillations present in mid- and high-latitude atmospheric flow: short-period (4 days) cycles associated with travelling short waves, the longer cycle (8 to 10 days) associated with the travelling disturbances with wave-numbers five to six, and a longer-period oscillation (20 - 30 days, the index cycle) associated with the quasi-stationary long-waves.

A simple dynamical explanation utilizes the thermal wind concept to argue that reduced eddy transfer of heat during the strongly zonal part of the cycle induces increasing shear of the zonal index and thus instability. The amplifying eddies increase the meridional heat transfer and reduce the thermal gradient, thus reducing the strength of the zonal component and the eddies diminish, starting the cycle again.

The modern mathematical view of this process involves the sequence of bifurcations that appear in forced motion. In general, for weak axisymmetric heating there is a large-scale symmetric solution. With increased heating, the symmetric solution gives way to a three-dimensional periodic solution. With further increase in heating, there is a subharmonic bifurcation to a multiple periodic solution. In Fourier phase space, this subharmonic bifurcation may be represented by the appearance in the longer wavelengths of an energy cycle that oscillates with a period two, three, or four times as long as the basic period. This pattern appears to correspond to a cyclonic period of some 5 days, a subharmonic period of 10 days, and an index cycle of 20 days. The evolution of the energy spectrum of the flow into quite different forms for high and low index regimes has been demonstrated by our empirical studies.

In both the simple dynamical and the mathematical view, the development and maintenance of the longer-period oscillation is a result of the forcing by differential heating exceeding a critical value. This corresponds with the observed fact that the multiple periodic flow is a wintertime phenomenon.

Plans for FY-82 and Beyond

The importance of better resolution of the global scale heating field and the possibility of long-term forecasts are both demonstrated by these observational results.

The main driving force for atmospheric motion on the global scale is the meridional thermal contrast between the low-latitude and polar regions. Our observational results show that variations in meridional heat flux are closely associated with the index cycle. Satellite measurements of outgoing radiation over the polar cap do not appear to be as closely associated with the dynamical processes. However, these are but two processes involved in the entire thermal budget of the polar cap, and we are now attempting to resolve this budget more accurately. Our present opinion is that satellite resolution of the polar cap heat budget may provide important indicators of impending flow transitions.

The oscillation of the energy containing components of the spectrum with both a basic and a subharmonic period suggest that an attempt be made to predict the evolution of these components of the flow. Such a prediction would be aimed, not at local weather conditions, but at global phenomena. Blocking may be viewed as a manifestation of the low-index part of the cycle and such a prediction might forecast both the onset and destruction of major blocking patterns.

An attractive approach is to consider the potential vorticity, which Ertel's theorem demonstrates is a material and global invariant for isentropic and inviscid flow. Changes in potential vorticity thus reflect heating or cooling. The potential vorticity theorem can be converted via approximations valid for small Rossby number and large Richardson number into the quasi-geostrophic equation, which governs an approximate form of the potential vorticity. Within the context of quasi-geostrophic theory, the potential vorticity is determined solely by the temperature field, and thus can be measured by satellite soundings along. Spectral techniques can

then be used to produce predictions of the evolution of the longest waves, utilizing satellite observations of initial fields and heating rates.

It is thus attractive to attempt to construct a spectral model for predicting global weather phenomena. Such a model is certainly not immune to the nonlinear effects that destroy predictability in conventional models, but these problems can be reduced by redefinition of predictability and by suitable parameterization of energy fluxes.

The redefinition is an important and nontrivial step. Predictions of local weather are usually judged on the phase, not the amplitude, of the forecast. Late arrival of a developing cyclone produces forecast error. But if we restrict our interest to a correct prediction of the distribution of spectral energy and ignore phase, then we may have a correct prediction within that framework even though phase errors were serious. We thus take advantage of the fact that spectral energies evolve slowly while phases can vary rapidly with respect to wave number and time. Such a restriction to spectral energies is indeed appropriate in the attempt to determine flow transitions, or the course of the index cycle.

Such a model could not predict evolution of the energy spectrum correctly without at least an approximate version of the spectral energy fluxes from smaller-scale systems. These fluxes depend on phase relations among the Fourier components, but it may be possible to obtain a statistically correct parameterization. We are exploring two innovations in the architecture of spectral models with these ideas in mind. The first invovles use of empirical orthogonal functions to resolve the large-scale dynamics of the flow adequately with a limited number of basic functions. The second is a method of using observed or model results to develop a parameterization of the statistical effect of the smaller components on the large-scales we hope to predict.

Publications

Mitchell, K. E., and J. A. Dutton, 1981: Bifurcations from Stationary to Periodic Solutions in a Low-Order Model of Forced, Dissipative Barotropic Flow. J. Atmos. Sci., 4, 690-716.

Dutton, J. A., 1982: Fundamental Theorems of Climate Theory -- Some Proved Some Conjectured. SIAM Review, in press.

MULTI-PERIOD SPECTRAL MODELS OF GLOBAL PHENOMENA

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SIGNIFICANT ACCOMPLISHMENTS FY-81

A major goal of our effort to utilize satellite observations to understand global weather phenomena is the development of theoretical ideas that can be verified and modified by the use of satellite observations. We have constructed a number of spectral models to test ideas about the atmospheric index cycle and blocking patterns. Eventually we plan to use more realistic patterns of heating which are derived from satellite earth radiation budget observations.

An important part of our theoretical effort has been devoted to understanding the mechanisms whereby the zonally-symmetric Hadley flows break down into the wavelike Rossby patterns typical of mid and high latitudes. The Hadley flow is driven by external radiative heating and to a lesser extent by latent heating a equatorial latitudes. The Rossby pattern seems to evolve when the zonal winds associated with the Hadley regime become baroclinically unstable. Mr. Harry Henderson has successfully developed a two-dimensional spectral model, based on the Boussinesq equations, of the Hadley flow in a cyclindrical geometry which simulates the earth's spherical geometry. Radiative heating is based on observations of Dutton (1976) and eddy viscosity is allowed for. This is one of the first efforts we know of that has been able to model the Hadley regime in as much detail. An analysis was then performed of the stability of the solutions to quasi-geostrophic wavelike disturbances. Mr. Henderson has been able to model in detail the transition over to the Rossby regime by this analysis. Fig. (1) shows in detail the transition region between the regimes and depicts the regions of the Rossby regime that are dominated by various horizontal wavenumbers. We were not able to extend the analysis into the area of large heating or thermal Rossby number Ro_T to investigate the transition back to a symmetric Hadley regime because the solutions for Hadley regime did not converge with large heating.

Studies of the Hadley and Rossby regimes similar to the above in much simpler geometries reveal that the transition between various wavenumbers in the Rossby regime is not a clearcut line as appears in Fig. (1) but occurs in a zone, Lorenz (1962). For instance in the transition between wave n and n+1 there is a region where either wave can dominate and the final transition from n to n+1 occurs along a line which differs from that for the switch-over from n+1 to n. This hysteresis is a common geophysical phenomenon. The atmosphere can probably be characterized as occasionally lying in such zones of transition and the

500 mb flow pattern could be highly transitory. A two-level spectral quasi-geostrophic model has been constructed to look at the detailed structure of the wavenumber transitions in the Rossby regime. So far we have been able to find the non-linear steady Rossby solutions and have discerned the regions of the Rossby regime dominated by each wavenumber. This model is unique in that it is valid for a spherical geometry with full account for the variability of the Coriolis parameter taken into account. We plan to integrate the spectral equations in the vicinity of the transition regions to determine the nature of the flow patterns.

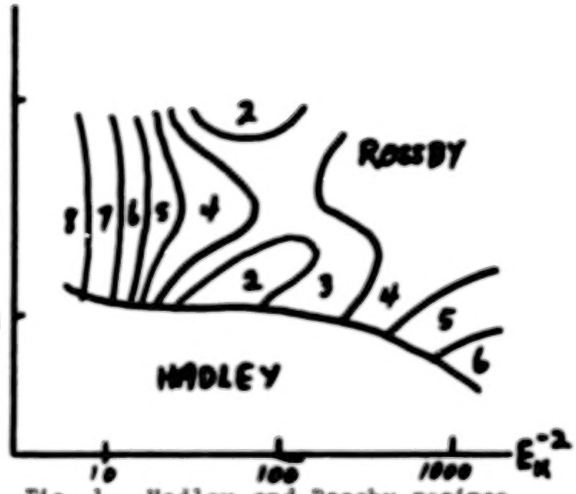

Fig. 1. Hadley and Rossby regimes. Ro_T is thermal Rossby number and E_K is Ekman number.

Two quasi-geostrophic phenomena which we have been especially interested in are the index cycle and blocking patterns. Charney and Devore (1979) have recently shown that the mechanisms governing the establishment of blocking patterns can be simulated with a simple two-layer quasi-geostrophic model. They show that such a model can have under certain conditions multiple steady state solutions and the atmosphere can switch over from one to the other via an instability of an intermediate state which is induced by orography. We have developed a similar model to look at the blocking phenomenon in more detail and to determine whether the index cycle can arise due to an instability of one of the steady states to a periodic solution, a Hopf bifurcation. Some features of our model are:

1) it is spectral with one east-west wavenumber and a mean flow represented at two levels
2) the waves are confined to lie in a mid-latitude β-plane channel bounded at 30 and 60°N
3) orographic forcing of the flow at a single wavenumber is allowed for
4) radiative forcing is specified by an externally-imposed north-south temperature gradient or equivalently a vertical wind shear ΔU_o
5) the model is baroclinic and thus the vertical shear of the mean wind can be altered by the action of the waves but the vertical mean wind U cannot be. The mean wind U is externally imposed and changes in response to momentum forcing across the walls of the channel.

We anticipate that the index cycle is a non-linear, periodic solution of the quasi-geostrophic equation. Fig. (2) shows the steady solutions to our model for fixed U and ΔU_o as a function of horizontal wavenumber. between wavenumbers 5 and 4 the symmetric Hadley solution becomes unstable and the new steady solution which branches off is singly periodic. When we integrated the non-linear spectral equations, the solution turned out to be doubly periodic - the fundamental period associated with the Roddby period and the second a multiple of that. The solution looks much like the atmospheric index cycle.

We also find that the model can switch over from a Hadley-like solution to a low index blocking pattern a certain critical values of the forcing functions. Fig. (3) gives an example and we shall show examples of the solutions to the time dependent equations as the sudden transition occurs.

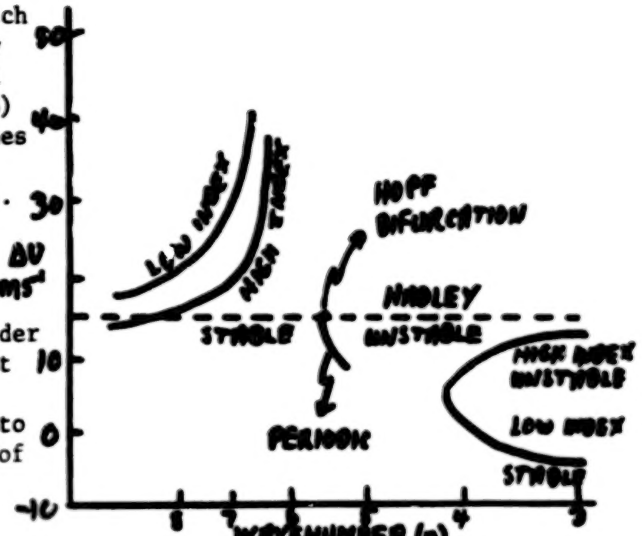

Fig. 2. Steady solutions. $U=\Delta U_o=15$ m s^{-1}.

PLANS FOR FY-82

Now that we have found that a low order spectral model can exhibit a behavior that strongly resembles the atmospheric index cycle and the blocking patterns, we plan to use the models to establish the behavior of these phenomena under a wide variety of conditions. From our observational work we plan to establish the characteristic patterns that the atmosphere assumes prior to the establishment of a persistent blocking situation and then we can utilize satellite observed heating patterns to anticipate blocking situations in the atmosphere. If indeed the index cycle is a multi-periodic phenomenon as our models indicate, we will determine from spectral analysis of satellite temperature and heating patterns the structure of these patterns and then see if the models can duplicate these patterns.

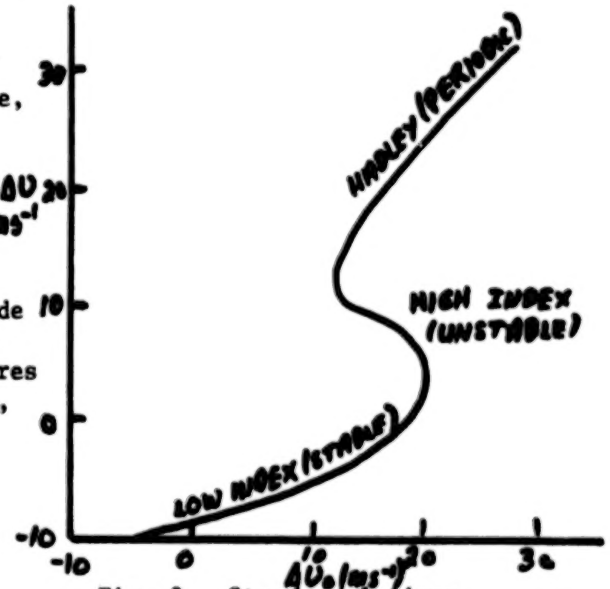

Fig. 3. Steady solutions. Wavenumber 3, U=20 m s^{-1}.

We need to generalize our rather crude spectral models to account for barotropic processes and more realistic wave structures both horizontally and vertically, however, before we can make realistic comparisons with the atmosphere.

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Title: The Role of Latent Heat Release in Baroclinic Waves - Without β-Effect

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Significant Accomplishments FY80:

In this paper we develop the analytical theory of two-level quasi-geostrophic baroclinic waves without β-effect aimed at understanding the role of latent heat release on the development of baroclinic waves.

When the release of latent heat is introduced with pseudo-adiabatic ascent and dry adiabatic descent, the width of the ascending region, a, is different from the width of the descending region, b, and furthermore, a static stability-vertical velocity correlation results in the mean state thickness increasing with time, however, the basic state shear is defined a priori, independent of the perturbations, in the formulation of the stability problem. Integro-differential equations for the perturbations are developed. Due to the mass continuity constraint, the unstable waves in the dry and moist regions are stationary in a frame of reference which translates with mean zonal wind at the middle level, and the growth rate in the moist region is equal to that in the dry region, same as in the dry model. Define the parameter $F=2f^2/S_d p_2^2 k_d^2$, where f is the Coriolis parameter, S_d is the static stability in the dry region, p_2 is the pressure at the middle level, and $k_d=\pi/b$. a/b is a function of F. For F>1, two unstable modes appear. The first mode has a narrow region of strong ascending motion and a wide region of weak descending motion (a/b<1), and the second mode has a narrow region of strong descending motion and a wide region of weak ascending motion (a/b>1). As $F\to 1$, the modes become steady and neutral and are characterized by (i) $a/b=(S_m/S_d)^{\frac{1}{2}}$ (S_m: static stability in the moist region), and (ii) $a/b\to\infty$. As $F\to\infty$, the modes are steady and neutral and are characterized by (i) $a/b\to 0$, and (ii) $a/b\to 1$. In comparison with the dry model, the structure of the first unstable mode shows that the ridge and trough of the streamlines shift slightly toward the region of sinking motion, and the warm advection occurs at the node of the vertical motion; while the structure of the second unstable mode shows that the ridge and trough of the streamlines shift slightly toward the region of rising motion, and the cold advection occurs at the node of the vertical motion.

The energetics formula shows the presence of a latent heat release term which contributes directly to the generation of eddy available potential energy. Although this term is small compared to the vertical and horizontal heat transports, latent heat release causes a significant change in the structure of the waves such that large departure in the horizontal heat transport from dry atmospheric values can occur.

The multi-component solution is also discussed. It is stressed that the first harmonic must be present and even harmonics are allowed provided the vertical motion is upward in the moist region of the width a and downward in the dry region of the width b. The solution is not Fourier decomposition in the normal sense, because the odd modes except for the first harmonic are not allowed.

Current Focus of Research Work:

The formulation of the role of latent heat release in baroclinic waves with β-effect is being developed. The preliminary calculations show the disappearance of modes except for one mode in the unstable spectrum for a given basic shear of the mean zonal wind. The problem of the cyclic condition in the wave structure is under investigation.

Plans for FY82:

The continuous model of Eady will be investigated. The extension of the Eady model to three-layer Eady-type model will also be investigated. The purpose is to study the moisture effect in the hierarchy of continuous models, and thus further our understanding of the sensitivity of moisture parameter in various continuous models.

Recommendations for New Research:

The model with the inclusion of the water vapor continuity equation in an initially unsaturated atmosphere should be considered in the new research. This will enable us to consider the conditional convective instability. The cloud equation should also be considered.

Publications:

Tang, C-M., 1980: The influence of the time change of static stability and wind shear on baroclinic waves. Pure & Appl. Geophys. 118, 706-719.

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Tang, C-M., and G. H. Fichtl, 1982: The role of latent heat release in baroclinic waves - without β-effect. (Submitted to J. Atmos. Sci.)

LATENT HEAT AND CYCLONIC SYSTEMS - A CASE STUDY

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ACCOMPLISHMENTS FY-81

Our main objective in FY-81 has been the determination of the effect of latent heating on the vertical motion field and energetics of the storm of March, 1978. We have used the formulation of the quasi-geostrophic omega equation of Hoskins (1975) in which the forcing function is expressed in terms of the horizontal divergence of a vector $\vec{Q}$. The advantage of this technique is that we avoid the problem with compensation between the vorticity and thermal advection effects in the conventional formulation. Our method of inclusion of latent hearing involves a modification of the static stability or equivalently the Brunt-Vaisalla frequency, σ, in regions where we anticipate that rising air is saturated. We have picked a region to solve the omega equation surrounding the storm which extends from 25N to 50N and 60W to 110W. Vertical motion due to orography and frictional boundary convergence are allowed for at the lower boundary. The upper boundary condition at 300 mb imposes a solution valid for a source-free omega equation. Lateral conditions are that the vertical motion field is gradient-free. Initial calculations were performed using hand-analysed Q vector fields but were found to be inadequate because of inconsistencies introduced by the analysis. We are now working with fields objectively analyzed by a program originally developed to prepare data fields for a meso-scale forecast model. An example of the results of our calculation is shown in Fig. (1) where the difference between the vertical motion field calculated with and without the effect of latent heating is shown. The boundary of the cloudy area where latent heating was allowed for is the heavy line. Clearly the heating increases upward motion in the cloudy area and there is some compensating subsidence outside the region. From the vertical motion field we have calculated precipitation fields assuming all the condensed moisture falls out of the cloud and none evaporates before reaching the ground. We find that the calculated precipitations are consistently much less than the observed. We have concluded that in spite of the fact that we have chosen winter storms where convective motions should be minimal and the slow quasi-geostrophic vertical motion field should be dominant, meso-scale motions are still present and play an important role in producing the observed precipitation.

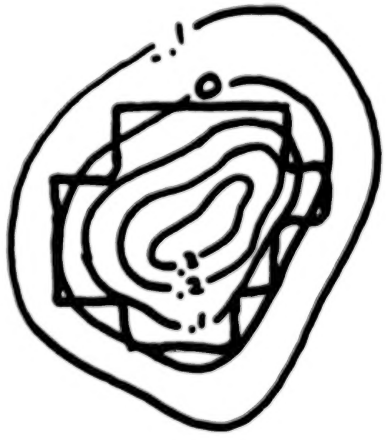

Fig. 1 Vertical velocity ($cm\ s^{-1}$)

We have used the quasi-geostrophic vertical motions to assess the role of the latent heating for this scale on the energetics of the storm. We have calculated the complete energy budget with and without the effects of the heating to assess the subtle effects of the heating.

Fig. (2) presents the energy cycle for March 25, 0000Z. We have assumed the eddy fields are exactly periodic in the domain of interest to simplify the calculations. Otherwise we would have had to use the formulation of the energetics of Johnson (1970), but we feel that correction due to the non-periodicity of the eddy fields is probably small enough to ignore. The latent heating has only minor effects on the baroclinic conversion of zonal available potential energy into eddy kinetic energy, but it does have an important effect on the conversion of zonal kinetic via mean meridional overturnings. In fact, for one time we found that the sense on this conversion was reversed by the latent heating from direct to indirect. We have carried out this process for the entire life cycle of the March 1978 storm.

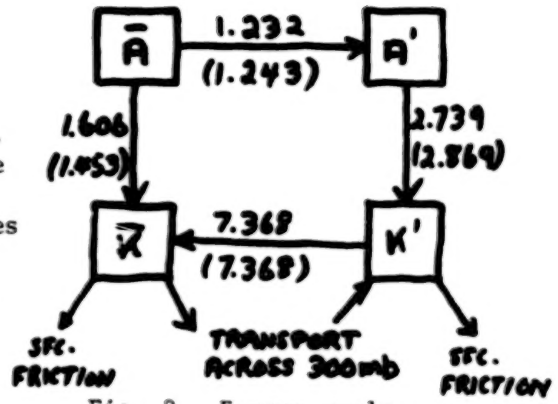

Fig. 2. Energy cycle, March 25, 0000Z

Once we realized the quasi-geostrophic latent heating field was only a small part of the total for this winter storm, we decided to account for other scales of motion in computing the vertical motions. Our first step in this direction was to work with the semi-geostrophic formulation of the equations of motion, where in contrast to the quasi-geostrophic system, horizontal advection by the ageostrophic as well as geostrophic wind is accounted for. Hoskins and Draghici (1977) show that the semi-geostrophic equations can be reduced to an omega equation of the same form as the quasi-geostrophic form in a transformed set of geostrophic coordinates. Normally this transformation cannot be accomplished if the flow field is diabatic, but we have shown that if the latent heating is accomplished by modifving the static stability the transformation can still be carried out. We are currently calculating the semi-geostrophic vertical motion fields for the March, 1978 storm and hope to have results shortly.

A final part of our tasks this year has been to formulate a numerical model to study the effects of latent heating on evolving baroclinic waves. While it is evident that modes of heating other than quasi-geostrophic are clearly important in the synoptic system we have studied, we plan to initially model quasi-geostrophic evolution. After making some preliminary calculations of stationary wave structures with a three-layer model shown in Fig. (3), where the intermediate layer is where the latent heating is only allowed to occur, it has become evident that the depth of the moist layer can be modified by the action of the wave and it is crucial to allowed this to vary during the wave evolution. Air currents rising from the ground where they are unsaturated will become saturated as they rise along their slanted paths in the presence of propagating planetary wave. Thus, the depth of the

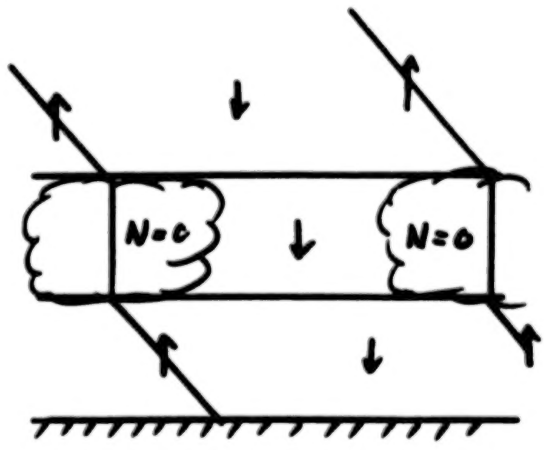

Fig. 3. Three-layer model

saturated layer will vary according to how much moisture is available for the rising air. The low-level field of moisture is in turn controlled by horizontal advection and by the field of precipitation. We are formulating a quasi-geostrophic model which explicitely treats the moisture budget to determine whether - cooperation between the fields of latent heating and the low-level moisture convergence field can significantly alter the evolution a baroclinic wave.

PLANS FOR FY-82

We shall complete the diagnosis of the effects of latent heating on the quasi and semi-geostrophic vertical motion fields for a number of winter storms. We plan to develop schemes for parameterizing the effects of small scale convective motions on the latent heating field. Apparently, one important means of initiating instability is the forced ascent of warm air above warm fronts which renders the lapse rate locally conditionally unstable, Browning (1975).

Our analytical treatment of evolving baroclinic waves will be continued and we plan to study the quasi-geostrophic as well as a hydrostatic equations. We hope with the latter set to examine the implications of various schemes to parameterize the joint effects of low-level moisture convergence and latent heating on the evolving wave structure.

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Title: Overview of the Atmospheric General Circulation Experiment (AGCE) Program

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Significant Accomplishments FY81:

In this overview only a brief and non-detailed description of the accomplishments and plans for each research activity of the AGCE Program is given, but the relationships among the activities, and the contributions of the activities to the total AGCE Program, are stressed. The accomplishments and plans of each specific research topic are discussed more fully in the presentations which follow. The approach taken for the AGCE Program has been to proceed on a relatively broad scientific front so that as well as producing engineering specifications for the AGCE instrument, a body of relevant scientific knowledge will be acquired for interpreting and understanding the AGCE data and for relating the data to real atmospheric flows. Such knowledge will also be valuable for the formulation of well-posed experiments with the AGCE instrument. The major accomplishments of FY81 are the following:

1. A Feasibility Study for the AGCE instrument was completed by the Space Division of the General Electric Company at Valley Forge, Pennsylvania.

2. Results were obtained from a numerical, spherical, hydrostatic model of the AGCE and were used as input for the Feasibility Study.

3. Results for the thermally-driven, rotating, axisymmetric, cylindrical annulus flows were obtained from a numerical model based on the Navier-Stokes equations. This model is referred to as the Warn-Varnas code (Warn-Varnas et al., 1978. J. Fluid Mech., 85, 609).

4. A numerical, spherical, axisymmetric model of the AGCE based on the Navier-Stokes equations has been developed. This model is referred to as the Roberts' axisymmetric code. It has been designed to be very flexible and, in particular, it can be easily converted to cylindrical geometry.

5. The Warn-Varnas code was successfully validated using accurate laboratory measurements of stratified spin-up in a cylinder. This work also constitutes a fundamental contribution to rotating fluid dynamics.

6. Studies of the effects of a vertical variation in gravity on baroclinic instability in simple models were completed. The results show that the effects of the radial variation of the dielectric body force are very small.

7. Analytical solutions were obtained for a nonlinear, rotating, Hadley cell and its stability. The model used in this work is a close approximation to the AGCE configuration.

8. The stripping-down of the NCAR Spectral General Circulation Model (GCM) was completed and a regime diagram determined.

Current Focus of Research Work:

The Roberts' axisymmetric code is being used to generate axisymmetric, basic states for a range of parameters of the AGCE. The stability of these basic states will then be determined using a linear stability version of the Roberts' axisymmetric code which is being developed. This work will assist in the preparation of engineering specifications for the AGCE instrument.

Plans for FY82:

1. Completion of the Roberts' linear stability code and determination of regime diagrams for the AGCE.

2. Validation of the Roberts' linear stability code in its cylindrical form against the experimental regime diagrams for the cylindrical annulus flows. These regime diagrams have not yet been derived quantitatively by theory.

3. Construction of a spherical spin-up apparatus for validation of Roberts' axisymmetric code in spherical geometry. This effort should also make fundamental contributions to rotating fluid dynamics.

4. Initiate the development of a spherical, three-dimensional model of the AGCE based on the Navier-Stokes equations.

5. Initiate analytical studies of nonlinear interactions in simple baroclinic models.

6. Continue studies with the stripped-down GCM.

7. Construct a laboratory apparatus which will be the cylindrical analog of the AGCE configuration.

8. Initiate laboratory studies of the dielectric liquids and photochromic dyes recommended by the Feasibility Study.

Recommendations for New Research:

A great deal of flexibility is being built into the computer codes now under development. This will mean that these codes can be used to study laboratory flows in cylindrical and spherical geometry as well as real geophysical fluid flows. It will be possible to assess and to proceed quickly with certain new ideas for studies relating to planetary atmospheric and oceanic flows.

List of Publications Prepared Since June 1980:

1. Eigenvalues of a Baroclinic Stability Problem with Ekman Damping. B. N. Antar and W. W. Fowlis. Journal of the Atmospheric Sciences, Vol. 37, No. 6, pp 1399-1404, 1980.

2. Review of, Rotating Fluids in Geophysics, Academic Press, New York, 1978. W. W. Fowlis. EOS, Transactions of the American Geophysical Union, Vol. 61, No. 39, 1980.

3. Sullivan's Two-Celled Vortex. F. W. Leslie. American Institute of Aeronautics and Astronautics Journal, Vol. 18, No. 10, p 1272, 1980.

4. Theoretical Regime Diagrams for Thermally Driven Flows in a Beta-Plane Channel in the Presence of Variable Gravity. J. E. Geisler and W. W. Fowlis. NASA Technical Memorandum 78316, 18 pp, 1980.

5. Baroclinic Instability of a Fluid in A Rotating Channel. B. N. Antar and W. W. Fowlis. (Abstract) Bulletin of the American Physical Society, Vol. 25, No. 9, p 1077, 1980.

6. The Applicability of the Piecewise Linear Current Profile in the Baroclinic Instability Problem. J. M. Hyun. Journal of the Meteorological Society of Japan, Vol. 58, No. 6, 1980.

7. Baroclinic Instability with Variable Static Stability - A Design Study for a Spherical Atmospheric Model Experiment. A. C. Giere and W. W. Fowlis. Geophysical and Astrophysical Fluid Dynamics, Vol. 16, pp 207-224, 1980.

8. Separate and Combined Effects of Static Stability and Shear Variation on the Baroclinic Instability of a Two-Layer Current. J. M. Hyun. Journal of the Atmospheric Sciences, Vol. 38, No. 2, pp 321-333, 1981.

9. Baroclinic Instability of a Rotating Hadley Cell. B. N. Antar and W. W. Fowlis. Accepted for publication in the Journal of the Atmospheric Sciences, October 1981.

10. Numerical Solutions for the Spin-Up of a Stratified Fluid. J. M. Hyun, W. W. Fowlis and A. Warn-Varnas. Accepted for publication in the Journal of Fluid Mechanics.

11. A General Solution of the Eady-Type Equation of Baroclinic Instability. A. C. Giere and W. W. Fowlis. Accepted for publication in Geophysical and Astrophysical Fluid Dynamics.

12. Numerical Solutions for the Spin-Up of a Homogeneous Fluid from Rest. J. M. Hyun, F. W. Leslie, W. W. Fowlis and A. Warn-Varnas. In preparation.

CALCULATIONS OF AXISYMMETRIC FLOW AND ITS STABILITY FOR THE AGCE MODEL

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Accomplishments of FY 81

The ultimate purpose of this research is to determine, by the use of numerical primitive equation models, where baroclinic waves might be expected in the AGCE apparatus. This will be accomplished by using an axisymmetric primitive equation model to compute, for a given set of experimental parameters, a steady state axisymmetric flow and then testing this axisymmetric flow for stability using a linear primitive equation model.

During this year we have completed construction and testing of the axisymmetric model. Calculations using this model have been completed for various rotation rates and temperature distributions in the AGCE apparatus. These calculations have been used to aid in design considerations of the AGCE equipment.

The model used to compute the steady state axisymmetric calculations does so by first integrating the traditional hydrostatic version of the primitive equations until a steady state is reached. Then additional terms are added to the diagnostic equation for pressure from the vertical equation of motion (in particular the friction and advection terms) and the model is again integrated to steady state (this second steady state is reached rather quickly). At steady state, this new flow is equivalent to that which would be obtained by a full nonhydrostatic model yet the cost is considerably less than that required of a fully nonhydrostatic calculation. Furthermore a comparison of the nonhydrostatic and hydrostatic steady state solutions show that except for very small regions near the poles and equator, the hydrostatic and nonhydrostatic solutions are virtually identical. The primary difference is in the width of the narrow vertical jets that form at the pole and equator. These results suggest that a full nonhydrostatic model for computing steady state solutions is unnessary.

We also have completed a linear model of the AGCE experiment in which only a single wave in the zonal direction is retained. Unfortunately, at the time of this writing this model has not yet been fully validated, and even preliminary results are not yet available. This model will be used to determine the stability of the axisymmetric flows calculated by the axisymmetric model.

Our current efforts are to complete testing the linear model and then use these models to obtain at least a crude estimate of the regime diagram for AGCE. Our plans for FY-82 are, therefore, to complete the calculations necessary to produce this diagram.

Recommendations for New Research

The regime diagram that will be produced under the current research has a pole-to-equator temperature difference which is the same on the inner sphere as on the outer. Our research has shown that flows more like the earth's atmosphere occur when the outer sphere is isothermal. Because the temperature gradients on the outer sphere are zero we would expect that the wave activity and hence flows within the apparatus would be quite different from the flows when temperature gradients are maintained on both spheres. Comparing the flows in the two configurations may provide further insight into the dynamics of the baroclinic waves. Therefore we recommend preliminary theoretical research into nature of the flows, including regime diagrams, in this alternate configuration.

In addition the AGCE apparatus offers a possible means for conducting simplified experiments to isolate and understand how certain dynamic processes force and maintain eddies in the General Circulation. Such experiments are currently possible only with general circulation models. For example, experiments to study the effects of mountains and land-sea contrast on the transient ultra-long waves may be possible in an experiment similar to AGCE. These might be patterned after general circulation model experiments which we are currently constructing for other contracts.

List of Publications

To date no publications concerning this research have appeared in the literature. However, we are currently preparing a paper describing our hydrostatic and nonhydrostatic axisymmetric calculations. We hope to submit this paper to a journal in the next couple of months.

Title: Cylindrical Numerical Models: Axisymmetric Basic States

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Significant Accomplishments FY81:

We have in our possession an axisymmetric, cylindrical code developed by Alex Warn-Varnas (Warn-Varnas et al., J. Fluid Mech., Vol. 85, 609, 1978). This code is based on the Navier Stokes equations and is for incompressible, Boussinesq flow. The equations and the initial and boundary conditions are finite differenced on a staggered mesh with nonuniform grid spacings. The resulting time-dependent difference equations are solved by a time-marching procedure. The stretching is used for boundary layer resolution. The pressure is found from a Poisson equaiton obtained from a divergence equation and is solved using an ADI iterative approach.

Using the Warn-Varnas code, a number of axisymmetric states for the thermally-driven, rotating, cylindrical annulus flows were computed over a range of parameters. The results were compared with earlier computations by G. P. Williams (J. Atmos. Sci., Vol. 24, 144, 1967 and J. Atmos. Sci., Vol. 24, 162, 1967). Excellent agreement was obtained. The Warn-Varnas code was also used to compute axisymmetric flows for the cylindrical analog of the AGCE configuration for input to the Feasibility Study.

It was originally our intention to use the Warn-Varnas code to compute regime diagrams to assist in preparing engineering specifications for the AGCE instrument. The plan was to prepare a linear stability version of the code and then using both versions to compute axisymmetric basic states and their stability for the cylindrical annulus flows. This work would have enabled us to validate the codes against the experiment regime diagrams for the annulus flows and this would have been a scientific contribution in its own right. Finally, the codes were to be converted to spherical geometry and a regime diagram for the AGCE prepared. However, further examination revealed that the Warn-Varnas code was somewhat out-of-date and that newer techniques would allow for faster and more flexible codes. We decided to determine the theoretical regime diagrams for the AGCF apparatus using spherical codes built from scratch and incorporating the latest ideas.

Current Focus of Research Work:

The Warn-Varnas code is no longer being used for the AGCE design studies.

Plans for FY82:

The Warn-Varnas code will still be used for spin-up and other fundamental rotating fluids studies.

Title: Utilization of Satellite Cloud Information to Diagnose the Energy State and Transformations in Extratropical Cyclones

Research Investigators Involved:

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George H. Fichtl, ES 83/MSFC, AL 35812, 205-453-0875

Accomplishments FY81 and Current Focus:

Since this project is only three months old, accomplishments to date are limited. Work over this period has concentrated on the selection of extratropical cyclone cases to analyze and the reduction of conventional data. Foremost among the criteria for making these selections are that

(1) the cases occur over a region and time period of abundant conventional meteorological data, and
(2) the cases be cyclones with widespread and significant precipitation and latent heat release.

With these criteria in mind, the first case chosen was one of dramatic cyclone development over the central United States during the period 9-11 January 1975. Standard 0000 and 1200 GMT rawinsonde data, hourly precipitation data, and National Meteorological Center sea level pressure, upper air isobaric, and radar analyses have been assembled for this case. All temperature, height, moisture, and wind data have been checked and gridded to a 140 km grid. In addition a search is in progress to identify the types of satellite data available.

Finally, to further test the quality of the data set, higher order quantities contained in the kinetic and available potential energy budgets are being computed.

Plans for FY 82:

Work will continue on selection of appropriate case studies and preparing data sets. These sets will be used to initiate calculations of complete energy budgets.

Leading these calculations will be the determination of diabatic heating fields and the adiabatic and diabatic components of the vertical motion. These in turn will be used to calculate the generation and release of available potential energy and vertical flux divergences of available potential and kinetic energy in order to evaluate the impact of diabatic heating on extratropical cyclone evolution. In all of this the effectiveness of satellite data in improving the heating estimates will be examined.

Spherical Numerical Models for the AGCE: Axisymmetric Basic States and their Stability

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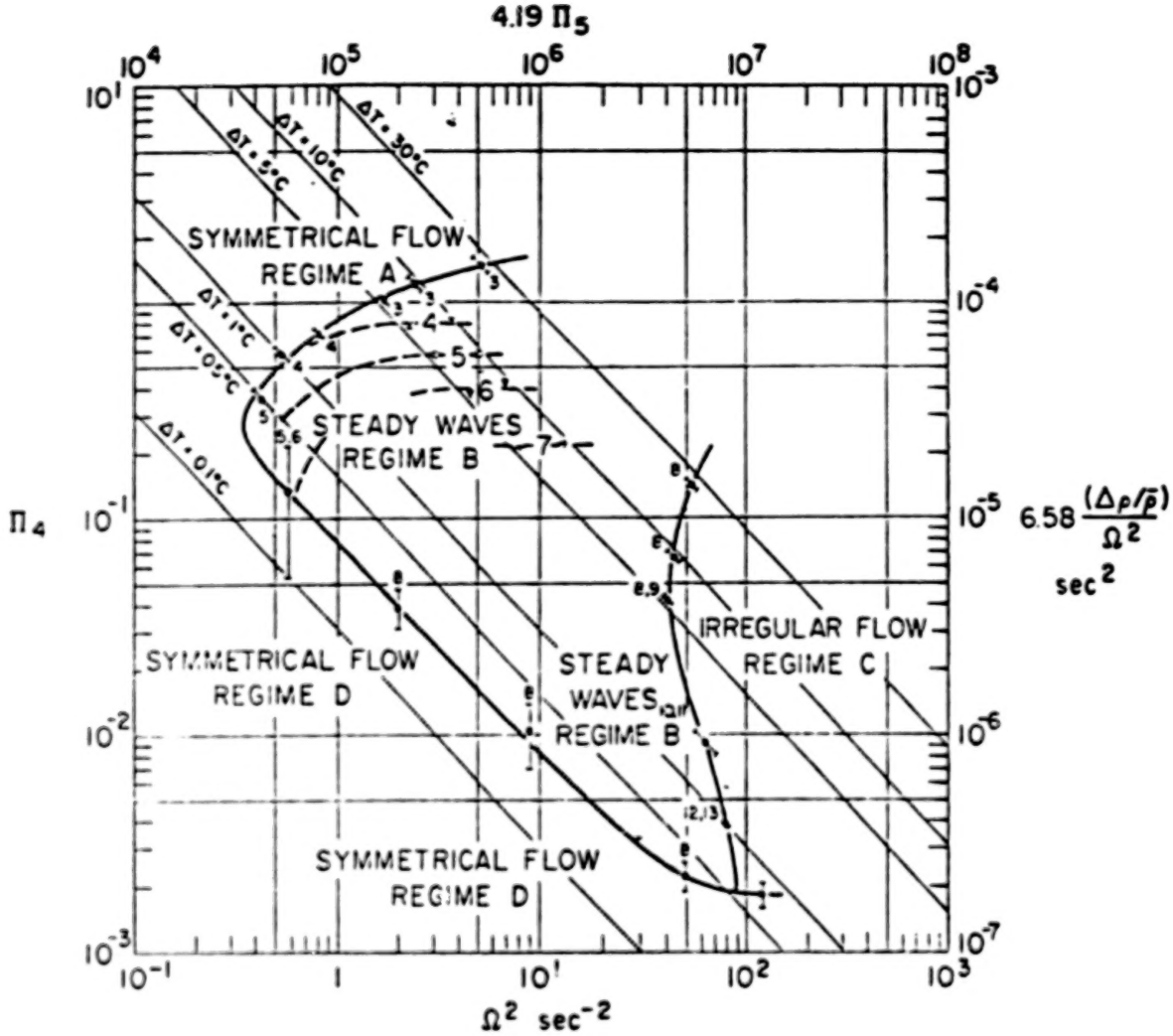
FY-81 Accomplishments

This section of the AGCE program began in March, 1981. Two computer codes are involved. The first calculates axisymmetric steady flow solutions. The second will determine the growth or decay rates of linear wave perturbations with different wave numbers. Growing solutions indicate instability. The results will be important for AGCE design, since the apparatus should allow experiments well within the unstable (wave) regime.

The figure on the next page is an experimental regime diagram for a particular cylindrical annulus geometry, as the rotation rate and temperature difference are varied. Our objective is to obtain similar theoretical diagrams for the boundary between the symmetric and wave regimes, with various proposed AGCE configurations. The codes can be validated by application to the cylindrical geometry and comparison with the experiments.

Results are required for a very wide range of AGCE design parameters and operating conditions. Thus efficient numerical algorithms are required to keep the computing requirements within reasonable bounds. We use nonuniform meshes and implicit iterative methods. These methods are related to time stepping, but with the time step different for each variable and mesh point.

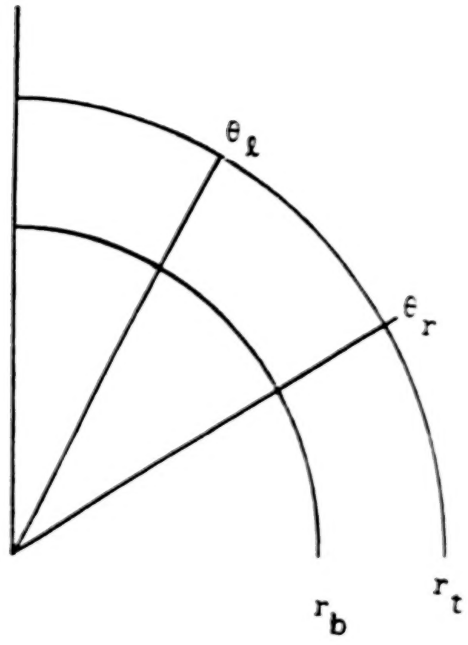
The domain for the codes is shown below. With appropriate choices of the boundary parameters, we can model a spherical shell, a hemispherical shell, a cylindrical annulus, or other geometries. The codes also allow for any combination of dielectric, terrestrial (axial) and centrifugal gravity. There is further flexibility in the boundary conditions on the flow (no-slip or free-slip) and temperature (imposed value or insulated). This flexibility is an important feature for design and validation purposes and for future applications.



$$\Pi_4 = \frac{gd(\Delta\rho/\bar{\rho})}{\Omega^2(b-a)^2} \quad , \quad \Pi_5 = \frac{4\Omega^2(b-a)^5}{\bar{\nu}^2 d} \quad , \quad \Pi_6 = \frac{\bar{\nu}}{\bar{\kappa}} \ .$$

a = 3.5 cm, b = 6 cm, d = 10 cm

Experimental Regime Diagram for Free-Surface Annulus Convection, using water.

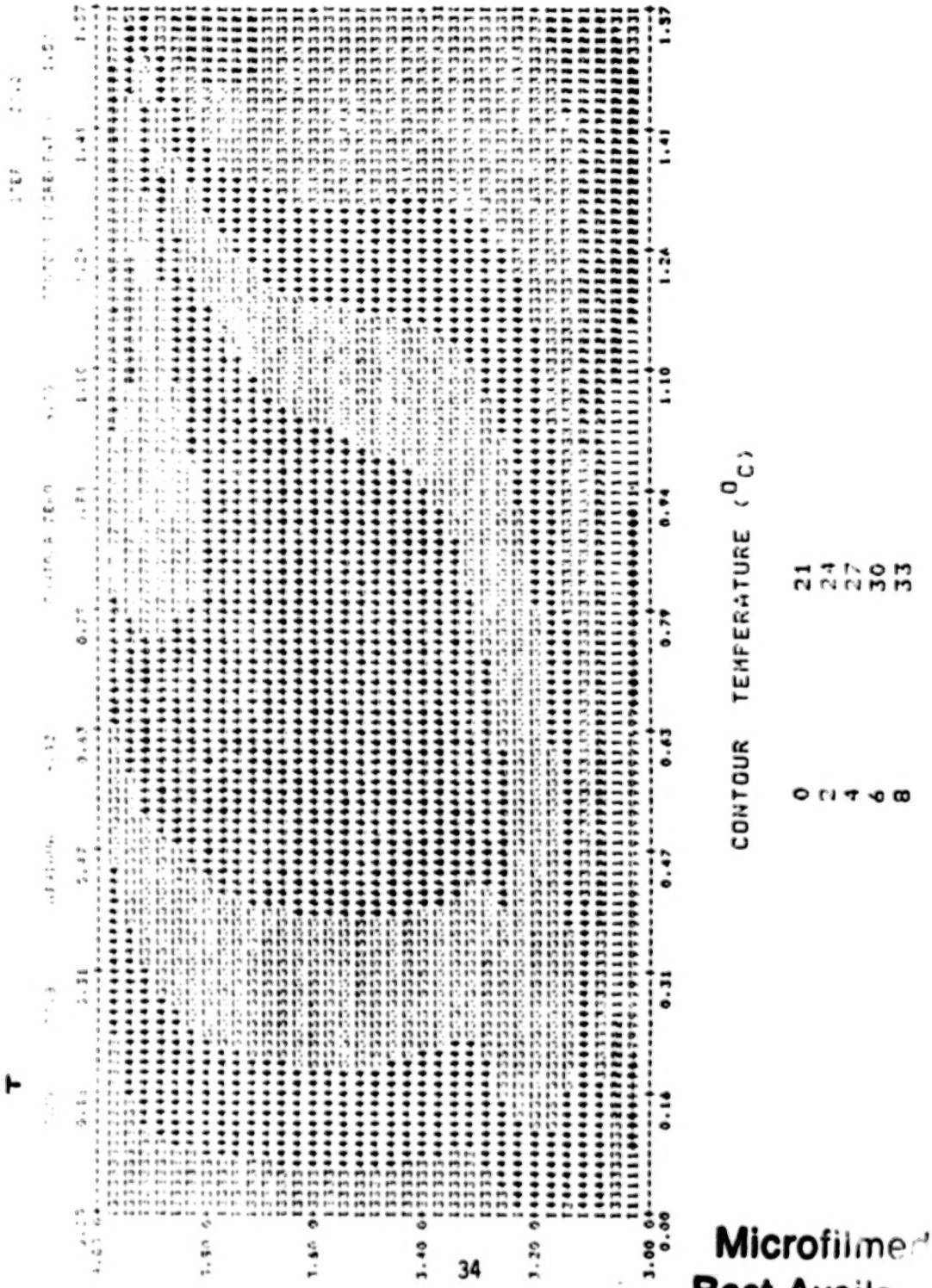


Case	Values
Spherical layer	$\theta_\ell = 0$, $\theta_r = \pi$
Hemisphere Cap	$\theta_\ell = 0$, $\theta_r = \pi/2$
Cylindrical Annulus	$\theta_\ell = \rho_\ell/R$, $\theta_r = \rho_r/R$ $r_b = R$ $r_t = R + h$

The Computational Domain and Special Cases

Current Focus

The steady state code is now almost fully operational. A steady state temperature solution is displayed below, for a hemispherical cap with radii 3 cm and 4 cm. The polar temperatures are 15°C and 25°C at the bottom and top; the corresponding equatorial temperatures are 25°C and 35°C. The flow has produced an ascending thermal plume at the equator and a descending plume at the pole. The graphics and numerical methods are being improved.



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FY-82 Plans

The numerical algorithms for the linear stability code will be finalized. The planned iterative method is related to time stepping the linearized equations, with an unknown growth or decay rate which is corrected each iteration. The time step is different for each variable and position. We expect the code to become operational by the middle of the year.

The two codes will be combined, to operate together in an efficient way, and generate regime diagrams. They will be validated on the annular geometry, and then applied to a series of projected AGCE designs and parameter ranges.

Recommendations for New Research

If the validations are successful, these codes will constitute an important NASA tool for studies in convective motions and baroclinic stability. They can potentially be used not only in support of AGCE design, but also to validate analytic theories and to interpret experimental and observational measurements related to atmosphere and ocean flows.

Publications

Roberts, G. O., 1981: Axisymmetric AGCE Flows and their stability. Proceedings of the April AGCE Conference, in Boulder, CO.

Three-Dimensional AGCE Numerical Model

Dr. Glyn O. Roberts

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and

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FY 82 Plans

The planned computer code will calculate steady and time-dependent AGCE flows, using the full nonlinear three-dimensional equations. Proposed experimental settings will be checked first, using model runs. Then actual experimental results (laboratory and Spacelab) will be compared with model predictions. This interaction between experiment and model will be very valuable in determining the nature of the AGCE flows and their relationship to analytical theories and to actual atmosphere dynamics.

The planned program will start in November, 1981. During the first year the numerical procedures will be determined, and code implementation will begin. We plan to complete and test the code in the second year. Validations will be performed in the third year, and proposed AGCE experiments will be modeled.

Recommendations for New Research

Beyond the scope of the proposed three-year program, we recommend numerical studies of the linear stability of steady three-dimensional baroclinic flows. The annulus experiments suggest that a small change in rotation rate or temperature difference can destabilize a steady nonlinear three-dimensional wave, with perhaps four waves, and produce either a steady solution with a different number of waves or an amplitude or wave number vacillation. Global atmosphere dynamics can show similar phenomena, and they may also occur in the AGCE tests. A linear stability model could aid in understanding these effects.

Title: Linear and Nonlinear Spin-Up/AGCE Numerical Model Validation Studies

Research Investigator Involved: J. M. Hyun
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Significant Accomplishments FY81:

A large computer code (Ref. 1) has been obtained and amended in order to study fundamental problems in rotating fluid dynamics. This code uses the primitive Navier-Stokes equations in axisymmetric form and employs finite-difference techniques on variable grids. The numerical results have been verified for spin-up of a homogeneous fluid in a closed cylinder (Ref. 1). Efforts have been made to resolve the spin-up flow of a stratified fluid in a cylinder. The numerical solutions were checked against the accurate disturbance-free laser Doppler measurements, and good agreement was obtained. It has been established that viscous diffusion in the interior, arising from the enhanced flow gradients in stratified spin-up, is the cause of the discrepancy between theory and experiments.

Current Focus of Research Work:

An investigation is being conducted on the strongly nonlinear problem of spin-up from rest of a homogeneous fluid in a cylinder using the aforesaid numerical code. The numerical results were compared against the laser Doppler measurements, and close agreement was found. The correct location and the viscous structure of the moving shear front are examined with the aid of the accurate comprehensive flowfield data. The basic assumptions adopted in the classical Wedemeyer model (Ref. 2) are reevaluated in light of the present numerical results. The limitations of the classical Wedemeyer model and its extensions are clarified, pointing to the difficulty in formulating the exact nonlinear Ekman compatibility conditions in finite geometry.

References

1. Warn-Varnas, A., Fowlis, W. W., Piacsek, S. & Lee, S. M. 1978 Numerical solutions & laser-Doppler measurements of spin-up. J. Fluid Mech. 85, 609-639.

2. Wedemeyer, E. H. 1964 The unsteady flow within a spinning cylinder. J. Fluid Mech. 20, 383-399.

Plans for FY82/Recommendations for New Research:

Plans are underway to examine numerically the spin-up flows in a cylinder when the top and bottom discs are given different final rotation

rates. Of particular interest will be the spatial and temporal dependence of the Ekman pumping conditions. When the fluid is stratified, this problem will illuminate the transient behavior approaching the steady state which is used as the basic state flow in baroclinic instability studies. In conjunction with the planned numerical investigation, laboratory apparatus will be designed which will provide accurate experimental verifications for the numerical results.

List of Publications Prepared Since June 1980:

J. M. Hyun, 1980: The applicability of the piecewise linear current profile in the baroclinic instability problem. J. Meteor. Soc. Japan, 58, 544-459.

J. M. Hyun, 1981: Separate & combined effects of static stability & shear variation on the baroclinic instability of a two-layer current. J. Atmos. Sci., 38, 322-333.

J. M. Hyun, W. W. Fowlis & A. Warn-Varnas, 1981: Numerical solutions for the spin-up of a stratified fluid. Accepted for publication in J. Fluid Mech.

J. M. Hyun, F. W. Leslie, W. W. Fowlis & A. Warn-Varnas, 1981: Numerical solutions for the spin-up from rest. To be submitted to J. Fluid Mech.

J. M. Hyun, 1981: Spin-up of a stratified fluid in a cylinder with conducting sidewall. Under preparation.

Theoretical Studies of Baroclinic Flow Related to the AGCE

By

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Significant Accomplishments FY-81: A study of the baroclinic instability of a rotating Hadley cell was completed and a paper reporting the major results of this study will appear in JAS in October 1981. In this study we investigated the influence of a prescribed horizontal, as well as vertical, temperature gradients on the baroclinic instability of a rotating fluid layer. Although the model was for a simple flat layer of fluid, it incorporated several features of the spherical AGCE model. Information is being gained on the design criteria of AGCE using this simple model.

The above mentioned model was extended to investigate the symmetric baroclinic instability of a rotating Hadley cell. Results are being gathered using this model and a paper summerizing these results is being prepared for publication. The most attractive part of the model is its simplicity while incorporating essential physical features of a realistic system. This is proving to be of great value in further understanding the symmetric baroclinic instability mechanism and its consequences. A laboratory experiment based on this model is being prepared at NASA/MSFC to test and verify some of the results of the analytical model.

A numerical code was developed to solve for the symmetric flow field in a rotating spherical annulus to model the symmetric basic state of AGCE. The numerical technique used is a mixed spectral finite difference method. A specific spectral expansion was developed and incorporated in the code. The coding is not yet finished and work is continuing on it.

Current Focus of Research Work: Work is underway to extend and use the simple basic state analytical profile which was developed for the rotating Hadley cell to study the nonlinear baroclinic instability mechanism. Although there is a great deal of work on nonlinear baroclinic instability, it is felt that the present effort will augment and fill some important gaps in the present understanding of this field. It is also hoped that the results of this study will help in better understanding of the nature and mechanism of finite amplitude waves that will exist in the AGCE. This study is both analytical and numerical.

Work is underway to extend the rotating Hadley cell model and numerical c de to help in the understanding of specific circulation models in shallow seas.

Plans for FY-82: To finish the numerical code for the symmetric basic state of the spherical annulus. To continue the nonlinear stability analysis for the rotating Hadley cell. To perform the experiments on the symmetric baroclinic instability.

List of Publications Prepared:

1. Antar, B. N. and W. W. Fowlis: Eigenvalues of a Baroclinic Stability Problem with Ekman Damping. J. Atmos. Sci., 37, 1980, pp 1399-1404.

2. Antar, B. N. and W. W. Fowlis: Baroclinic Instability of a Fluid in a Rotating Channel, Bull. Am. Phys. Soc., 25, 1980, 1077.

3. Antar, B. N. and W. W. Fowlis: Baroclinic Instability of a Rotating Hadley Cell, J. Atmos. Sci, 38, 1981, xxx-xxx.

4. Antar, B. N. and W. W. Fowlis: Baroclinic Instability of a Rotating Hadley Cell: Symmetric Instability. In preparation.

Title:

Flow Regime Studies with a Simplified General Circulation Model

Research Investigators:

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Significant Accomplishments FY-81:

In the Atmospheric General Circulation Experiment (AGCE) apparatus a fluid is confined between co-rotating spheres in the presence of a simulated radial gravity and a meridional temperature gradient on the inner sphere. This situation is much closer to the atmosphere than is the traditional laboratory analogue, which consists of an annulus of fluid confined between co-rotating cylinders oriented parallel to terrestrial gravity. We have modified an atmospheric general circulation model to the point where it looks as close as possible to the AGCE apparatus (no clouds, no radiative transfer, smooth lower boundary, etc.) We are presently operating this model in the laboratory experiment mode, treating the meridional temperature gradient and the rotation rate as parameters at our disposal. Our objective is to acquire the basic knowledge necessary for application of the AGCE data to the understanding of large-scale atmospheric dynamics.

In the traditional (that is, annular geometry) laboratory experiments the horizontal temperature gradient and the rotation rate appear in dimensionless parameters called the thermal Rossby number and the Taylor number, and the observation as to whether or not waves are present is noted in a diagram (called the regime diagram) with these two dimensionless parameters used as ordinate and abscissa, respectively. The curve in this diagram separating the region where waves occur from the region where waves do not occur is referred to as the stability boundary. Linear baroclinic instability models with Ekman damping present have been successful in reproducing the shape and (to some extent) the location of the stability boundary found in the annulus experiments.

Our main research accomplishment this year has been to find and map out the features of a stability boundary that exists in our modified general circulation model. To our knowledge this is the first time that this major feature of a regime diagram has been derived from numerical experiments using a fully nonlinear primitive equations model on a sphere. This stability boundary appears to have the same characteristic shape as that of the annulus experiments, and its location in the regime diagram is roughly in accordance with predictions from a linear baroclinic instability model on a beta plane.

The square root of Taylor number, used as the abscissa in the regime diagram, contains among other things the inverse first power of the viscosity coefficient. Consequently, the location of the stability boundary in the regime diagram is sensitive to the amount of viscosity present. Our model contains a horizontal eddy viscosity and a vertical eddy viscosity. We are presently nearing the end of a series of experiments designed to assess the relative effects of these two types of damping on the location of the model stability boundary. Our tentative conclusion is that the vertical eddy viscosity is dominant. We have recently become aware that the vertical eddy viscosity as it exists in the model really has two parts: the stress at the lowest model grid point is specified by a quadratic surface drag law with fixed drag coefficient and the stress at all other model levels goes like the product of a diffusion coefficient K and the vertical shear of the horizontal flow. Many of our results to date, including our assessment of the location of the stability boundary in the regime diagram, have been obtained from runs in which we varied K but failed to vary the surface drag coefficient. We have eliminated this problem by specifying that the stress go like K times shear everywhere and imposing a no-slip condition at the lower boundary. We are presently running many of our cases over again with this new boundary layer formulation, anticipating that this new modification will change the location of the stability boundary but will not significantly alter its shape.

Plans for FY-82:

Once we have the firmly established the shape and location of the stability boundary and understand in terms of model dynamics why it is where it is, we will go on to explore specific features and characteristics of wave fields present. First on our list will be a search for the region in the regime diagram where wave vacillation occurs, then we will try to map out the subregions where the period of the vacillation is long and where it is short. We will analyze individual cases of vacillation and examine the energy cycle, comparing our results with what is known from the vacillation studied in the annulus experiments. We will also seek to find subregions in the regime diagram where the wave field is dominated by a single wave and at the other extreme, where so many waves are present that the flow field is irregular. As a further extension of our work which will make full use of all the data generated from our many model runs, we propose to regard our model as a climate system whose external parameters are an imposed meridional temperature gradient and rotation rate and will seek to define the climate by systematically assembling mean quantities and fluctuation statistics from these data.

Publications since June 1980:

None.

Title: The AGCE Instrument Feasibility Study

Research Investigator Involved: William W. Fowlis
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Significant Accomplishments FY81:

Preliminary scientific design calculations had determined that the AGCE apparatus has to be different from the GFFC in three major respects:

1. A large, stable, radial temperature gradient with associated inwards heat flow has to be maintained.

2. The diameters of the spheres have to be increased.

3. A larger value of the liquid dielectric constant and/or a higher voltage are required.

It was also clear that it was not practical to scale-up the optical system of the GFFC to accommodate the larger spheres required for the AGCE new concepts for the flow and temperature measurement were needed. These requirements led to a Feasibility Study which was awarded to the Space Division of the General Electric Company, Valley Forge, Pennsylvania, January 81. The task list was as follows:

1. Dielectric liquids survey

2. High voltage and high frequency sources

3. Dust removal

4. Observation of the flow and data storage

5. Optical field of view

6. Thermal control

7. Control of the total apparatus

8. Material for the outer sphere

9. Configuration of the total apparatus

10. Design and fabrication costs

The Feasibility Study was completed during July 81 and much was accomplished. The following is a summary of the results.

1. A new concept for the flow and temperature measurement using an optical scanner was worked out. This device will be able to make measurements to the specified accuracy and will not require the large lenses of the GFFC.

2. Several high dielectric constant liquids with compatible photochromic dyes were recommended. These liquids satisfy the many other constraints of the AGCE apparatus, but their relatively high values of electrical conductivity may still present problems.

3. A voltage source of up to 15,000 volts rms which meets our specifications is feasible.

4. The optical and thermal specifications for the outer sphere mean that sapphire is the only suitable material. A large enough boule can be grown to meet our size requirements but the hemisphere will have to be cut from the boule such that the optic axis will rotate in the equatorial plane. This in turn means that birefringence effects will be present in the scanner but only a small degradation of the measurement accuracy will result.

5. The remaining tasks, dust removal, thermal control, total apparatus control and apparatus configuration can all be accomplished with standard technology. It was recommended that all data be telimetered directly to ground; this will allow for real time examination by the scientific investigation and hence for more flexibility with the AGCE experiments.

Current Focus of Research Work:

We are continuing to assess the Feasibility Study.

Plans for FY82:

In general, in liquids, a high dielectric constant is associated with a high electrical conductivity. Purification can reduce the conductivity. Purification procedures recommended in the Feasibility Study will be examined. The photochromic dyes recommended will also be examined.

Title: GFFC Instrument Development and Spacelab 3 Mission Activities

Research Investigators: Dr. John Hart
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Dr. George H. Fichtl
Dr. William Fowlis
NASA/Marshall Space Flight Center
Mail Code: ES82
Marshall Space Flight Center, AL 35812

Dr. Peter Gilman
High Altitude Observatory
National Center for Atmospheric Research
Boulder, CO 80303

Significant Accomplishments FY81:

Instrument Hardware: The FY81 work effort was devoted to final fabrication and testing and checkout. At the beginning of the reporting period, engineering design changes and repairs were being made to correct structural failures that occurred during vibration tests of the GFFC performed prior to the beginning of the reporting period (July 1980). The failures consisted of 1) a weld failure which bonded the LED data display housing to the GFFC optical system, 2) failure of the oil bellows support rack, and 3) failure of GFFC oil bellows. The fixes for these failures, which resulted from a review held at MSFC, consisted of 1) improving the weld of the LED housing to the GFFC optical system, and adding structural members between the LED housing and the instrument proper to provide more rigidity, 2) adding structural strength to the oil bellows housing and 3) repair of the failed oil bellows and performance of leak tests on the bellows that did not fail to assure a set of four functioning oil bellows. EMI testing and final shake tests are now underway.

In February 1981, Dr. John Hart and Dr. Juri Toomre, visited the Aerojet facility at Azusa, California to review progress on the instrument, obtain test data film, and inspect the GFFC instrument. It was concluded that a number of minor changes were needed. These included electronic filters to stabilize the LED display readouts of GFFC sphere temperature, light filters to balance the north-south and east-west shadowgraph film grayness for recovering temperature field data, modification of the LED display readout to indicate picture type (N-S, E-W, of photochromic dot picture), replacement of a Zener diode so as to reduce voltage level associated with ultraviolet flash to excite photochromic dyes and hence reduce the intensity of the ultraviolet light to preclude over exposure

of the photochromic substance in the working fluid. As a result of discussions between the instrument scientist, lead engineer, and Aerojet, the corrections required by the GFFC Science Team were incorporated by the Aerojet without incurring additional costs.

As a result of EMI tests performed prior to February 1981, six temperature sensors located below the surface of the inner sphere failed. However, because of redundancy (two sensors at each latitude), the GFFC still has temperature measurement capability and hence control at each of the inner sphere latitudes at which the GFFC heaters are located. However, it was noted by Aerojet that the temperature sensors in question failed at a temperature a few degrees higher than 45°C. As a result Aerojet has constrained instrument operation to temperatures of 45°C and below. The design requirements call for a GFFC which can provide inner sphere operating temperatures as high as 55°C and automatic shut-down capability when inner sphere temperatures exceed 60°C. The fix that has been agreed upon by the Science Team, Spacelab Payloads Project Office, and NASA Headquarters consists of 1) testing the instrument for period of 30 hours and accepting it if no further temperature sensor failures occur and 2) including software and hardware to sense a failed sensor on-orbit and shut-off the heater at the latitude where the failure occurs so that experiments can still be performed in the unlikely event of additional failures on-orbit, otherwise a runaway heating condition will occur at the failed latitude.

Data Management Plan: A data management plan has been prepared and has been mailed out for review by the Science Team and appropriate NASA management. The data management plan encompasses the total GFFC project including software development, computer purchases, ground-based tests, data flow, postflight data analysis, documentation, and archiving of the GFFC flight film along with experiment descriptions and information concerning the thermodynamic and dynamic state of the Spacelab/Orbiter during the GFFC experiments on the Spacelab 3 Mission.

Preparations for Bringing GFFC to MSFC: Preparations for bringing the GFFC instrument to MSFC have been underway since the first of this calendar year. Dr. Fred Leslie/ES82 has been assigned the task of making these preparations. He will be the prime operator of the GFFC at MSFC. He has received the necessary MSFC training for handling flight hardware. A list of equipment to support ground based tests has been prepared with the lead engineer. This list includes a power supply, an air flow source, air ducting, semiconductor chips, instrument programming equipment, etc. In addition, a clean room has been identified in Building 4487 (Room B173) for performance of ground based tests and storage of the instrument.

Spacelab 3 Mission Interfaces: Work progressed smoothly during the reporting period relative to assuring that GFFC/SL3 interfaces were satisfied. A key milestone was the baselining of the GFFC Experiment

Requirements Document (ERD). As a result the SL3 Mission has accepted our requirement of 84 hours of on-orbit GFFC operation time. The current SL3 timeline accommodates this requirement.

Current Focus of Research Work:

The current work activity is aimed at implementing the hardware/software changes and performing the necessary tests to resolve the technical issues centering on the failed temperature sensors and completing the EMI and shake tests.

Plans for FY82:

During FY82 we plan to 1) complete the work associated with testing the inner sphere temperature sensors and completion of the software/hardware to accommodate temperature sensor failures on-orbit, 2) participate in the SL3 Integrated Design Evaluation (IDE) and satisfy SL3/GFFC milestones, and 3) complete the necessary preparations to bring the GFFC instrument to MSFC and 4) initiate GFFC tests at MSFC to support Science Team activities.

Title: Studies of Solar and Planetary Convection for GFFC

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Significant Accomplishments FY80:

1. Several fully non-linear, three-dimensional, unsteady numerical simulations of flows expected in the Geophysical Fluid Flow Cell were completed. Common to all these integration are hemisphericity (with a horizontal insulating barrier at the equator), $1/r^5$ gravitational acceleration, rotation, and spherically symmetric heating (hot inner sphere, cool outer sphere). The general conclusion from these studies are:

a) Flows for $1/r^5$ gravity are almost indistinguishable from those with $1/r^2$ or constant acceleration.

b) For moderate to high Taylor number (30,000 to 300,000) and moderately supercritical Rayleigh number, the differential rotation is only significant at high latitudes. There, it is a result of Coriolis turning on East-West oriented cells. Rigid walls lower eddy velocities and reduce any Reynolds' stress driven equatorial acceleration.

c) The dominant eddy type for the cases described in b) are North-South rolls in equatorial region (cell scale approximately equal to fluid layer depth), and quasi-East-West rolls at high latitudes.

2. A two-dimensional numerical simulation of compressible thermal convection of a non-rotating gas was completed. The general aspects of convection are only slightly modified from the Boussinesq (incompressible) case provided the atmosphere is less than about five scale heights deep. (The rigorous

Boussinesq limit implies depths substantially less than a scale height.) These results give us confidence in extending GFFC results to fundamental processes in planetary atmospheres.

3. GFFC, theoretical, and other laboratory models of convection all suggest that the dominant horizontal convection scale is on the same order as the fluid depth. However, satellite pictures of meso-scale convection over the ocean indicate horizontal scales of motion many, many times greater than the vertical scale. An effort was made to understand this important difference. A linear stability calculation for convection that includes both latent heat release, and entrainment of stable air from aloft by microscale turbulence was completed. This calculation showed that the differential entrainment of a growing cell acts like an insulating wall (actually a 'super' insulating one) and cause the maximally growing linear disturbance to have a very large wavelength/depth ratio.

4. Software to obtain digitized data from the GFFC film was written. So far programs to re-register the image, decode diode matrix data, and digitize the Schlieren images are operational.

Plans for FY82:

The main focus of research will be concerned with ground-based testing of the GFFC instrument. Experiments will be carried out at Aerojet, and later at Marshall, that include runs in the inverted/stable mode with the hot inner sphere above the cool outer sphere in the Earth's gravitational field. In this configuration the motions are expected to be slow and axisymmetric for a wide range of external parameters. Thus comparisons can be made with existing theoretical models for convective flow in enclosed cavities, models that have already been verified by comparisons with experiment. This exercise will allow us to exercise the data reduction/analysis system and to calibrate the optical Schlieren system on the GFFC.

We shall attempt to do some low resolution 3-d numerical models of GFFC convection at moderate to high Taylor numbers and high Rayleigh number (Ra~600,000). It is hoped that this parameter setting will lead to a larger amount of Reynold's stress driven equatorial acceleration than previous cases that had only modest supercriticallity.

The model of compressible convection shall be extended to three dimensions, to see if compressibility can influence the plan-form selection mechanisms.

Other calculations will be carried out as the need arises. For example, we anticipate that if the orbit axis of SL3 is shifted off the current 5^{o} out of plane band in response to the needs of ATMOS, we will have to re-assess the possible occurrence and amplitude of precessionally driven motions in GFFC.

Publications:

Hathaway, D., P. A. Gilman, J. A. Toomre. Convective instability when the temperature and rotation vector are oblique to gravity, Part II. Real Fluids with Effects of Diffusion. Geophysical and Astrophysics Fluid Dynamics. Vol. 15, page 71.

SECTION III. SEVERE STORMS AND LOCAL WEATHER RESEARCH

The NASA program of Severe Storms and Local Weather Research is to conduct applied research and development using space-related techniques and observations that will increase the basic understanding of storms and local weather which will help to improve the accuracy and timeliness of local weather forecasts and severe weather warnings.

James Dodge

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Title: Lightning Mapper Development - Program Overview

Research Investigators Involved: Dr. Hugh Christian
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Significant Accomplishments FY81:

Developed new instrumentation to measure the optical characteristics of lightning. These instruments include an optical array sensor which is designed to measure the spatial and temporal characteristics of lightning in any background light reflected from cloud tops, an optical pulse detector with microsecond temporal resolution covering the same field of view as the optical array sensor, and a high resolution spectrometer producing a lightning spectrum with nearly angstrom wavelength resoltuion every few milliseconds.

These sensors, together with an electric field change meter, a wide field of view optical pulse detector, CCD television camera and two time lapsed cameras, were integrated into a NASA/ARC U-2 aircraft and flown over thunderstorms during August 1981.

Current Focus of Research Work:

Our present research is directed toward obtaining the quantitative lightning data that is needed for the development of a satellite-based lightning detection and location system. The type of data required includes measurement of

a. absolute intensity and variability of the light reflected from cloud tops,

b. absolute intensity and variability of lightning generated optical emissions radiating from cloud tops,

c. absolute intensity and width of lightning spectral emission lines.

Our primary means for acquiring the necessary data has been to fly the ARC U-2 (carrying the previously described

instrument package) over thunderstorms during both daytime and nighttime and measuring lightning characteristics. It is expected that this approach will ultimately reduce the data that is required for progress of the lightning mapper definition study.

Plans for FY82:

We expect to continue our focus on the U-2 research effort during FY82. Changes to the U-2 instrumentation package will include the addition of a higher resolution spectrometer and a CAMAC based transient digitizer/recorder system. In addition, we plan to include the time resolution of the optical array sensor and test a prototpye background subtraction system.

Additional research efforts will include:

a. Initiation of a formal lightning mapper definition study. Explore availability of AF "piggyback" sensor flight.

b. Detailed study of potential ground-based RF systems for hybrid applications. Candidate systems include ELF (Taylor, NSSL), phase linear interferometers (Johnson, SWRI), and a LLP network.

c. Study of hurricane electrification using dual phase linear RF interferometer; one installed at San Antonio, Texas and one at Huntsville, Alabama.

d. Continue high time resolution UHF measurements.

e. Study of the relationships between storm severity and lightning activity.

Recommendations for New Research:

Use the BLM western lightning network in conjunction with ground-based radar and weather satellites to study storm development and propagation.

List of Publications Prepared Since June 1980:

Christian, Hugh J., "Detection of Lightning from Space Preliminary Study."

Christian, Hugh J. and William W. Vaughan, "Lightning Detector and Location Techniques."

Title: Thundercloud and Lightning Observations Made from Above in Connection with NOSL

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Dr. Marx Brook
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Significant Accomplishments:

Activities during the past year have been primarily concerned with preparation for the NOSL experiment to be flown as part of OSTA-1 on STS-2 to be launched September 30th. The data obtained with the NOSL equipment on the ground at the National Severe Storms Laboratory by O. H. Vaughan of Marshall Space Flight Center and synchronized by the laboratories in Huntsville has shown that good photographic records and spectral data of lightning can be obtained with the camera and correlated with the tape recorded data from the photocell optical system.

To obtain ground truth information required for the interpretation of the photocell data that will be taken from the Space Shuttle, a series of flights has been made with a U-2 aircraft instrumented to take photographs of thunderstorms from above. A grating is used with the camera at night to obtain spectra, and signals from a photocell optical system and a slow antenna characterizing the lightning are recorded on a wide band recorder. These data are presently being analyzed at New Mexico Tech and at SUNYA and will be reported elsewhere.

The photographs taken from the U-2 in May 1981, at an altitude of 65,000 feet over a thunderstorm near Atlanta, Georgia, whose top was at an estimated altitude of 28,000 feet, are similar in many respects to those obtained the year before over a much larger storm at 42,000 feet in Arkansas.

Both series of photographs show a number of lightning channels visible in the clear air above the strongly convective cummuliform cloud top. No photographs thus far have shown instances of long vertical channels from the cloud top into the stratosphere such as those that have been described in the literature. It is clear, however, that there are channels above the cloud as long as several kilometers in horizontal extent. In the case of large storms whose convective towers penetrate into the stratosphere, it is evident that these lightning discharges may introduce chemical by-products directly into the stratosphere.

Plans for FY82:

Continue work on all required interfaces between MSFC and JSC for future NOSL flight experiment and training of Shuttle crew members.

More U-2 flights are planned for Spring 82 and Summer 82 for collecting lightning signatures from onboard and ground truth instrumentation.

Continued development for an improved NOSL experiment for reflight on Shuttle.

Recommendations for New Research:

The cause of the lightning discharges that can be seen looking down on a thundercloud is puzzling. Possibly they are unipolar in nature, relieving electrical stresses by transporting charge from an intense charge accumulation in the upper part of the cloud into charge-free regions of clear or cloudy air. Alternatively, they may be discharges between regions of positive and negative space charge in the upper cloud. It will be of interest to carry out similar observations above thunderstorms occurring over the ocean. If space charge produced from the earth's surface beneath the cloud is being carried into the upper part of the cloud by convection and is playing a part in this phenomenon, there may be much less lightning visible in the tops of maritime thunderclouds.

It is recommended that detailed studies be made of lightning and C. T. R. Wilson conduction currents above the tops of energetic thunderstorms occurring over large bodies of water.

o Compare ground and U-2 observations using cine - cameras, optical NOSL, and video camera systems and RF techniques for collecting lightning signatures.

o Develop more advanced data analysis techniques for NOSL using computers.

o Develop additional airborne sensors and electronics packages for use in Aircraft - Thunderstorm Overflight Programs.

List of Publications Prepared Since June 1980:

Thunderstorm Overflight Program, AIAA Paper 80-1934-CP, O. H. Vaughan, Jr., B. Vonnegut, R. Orville, M. Brook, R. Tennis, C. Rhodes, and D. Rust, AIAA Sensor Systems for the 80's Conference, Colorado Springs, Colorado, December 2-4, 1980.

Title: Correlation of Ground-Based Lightning Experiments in Florida, New Mexico, Texas, and Oklahoma

Research Investigators:

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Dr. Bobby N. Turman
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Significant Accomplishments FY 81:

1. Coordinated delivery of lightning ground data from three research groups for correlation with the DMSP satellite lightning detector.

2. Discovered that correlation varies considerably with ground site. When lightning occurrence rates are high in Oklahoma (Sesame) and Texas, 25% of the ground negative return flashes correlated with satellite optical triggers. However, in Florida the correlation is usually above 50%.

3. There appears to be no correlation between pulse duration and polarity of the flash as first hypothesized.

Current Focus of Research:

We are currently bringing together the diverse data sets so as to put together a cohesive data base of satellite ground lightning observations.

FY 82 Plans:

The present data analysis was limited to satellite data with a 4-second integration time. We would like to correlate satellite data with msec timing with ground data. The best data set, when our high time resolution sensor was operating, was collected by Mike Maier of NOAA in South Florida in summer 1980. However, AFTAC has been very slow in processing the DMSP data and is only to November of 1979 at last word.

Publications and Presentations:

Turman, B. N., and R. J. Tettelbach, Synoptic-Scale Satellite Lightning Observations in Conjunction with Tornados, Monthly Weather Rev, 108, 1878, 1980.

Turman, B. N., and B. C. Edgar, Global Lightning Distributions at Dawn and Dusk, accepted for publication, JGR.

Edgar, B. C., Distribution of Superbolts, presented at the Atmos. Elect. Conf. Manchester, England, August 1980.

TITLE: Video Observations of Lightning Spectra

RESEARCH INVESTIGATORS:

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SIGNIFICANT ACCOMPLISHMENTS FY81:

During the past year the results obtained from the 1980 observations of lightning spectra at Socorro, New Mexico were reduced. The purpose of the observations was to gain information regarding a large statistical sample of cloud-to-ground and intracloud lightning events. A low-light-level intensified silicon intensified target (ISIT) vidicon camera was used for the observations. The camera was mated with a f/1.6 25 mm lens and a 600 line/mm grating blazed to 5000 Å. Roughly a 20° x 30° field of view is subtended with this system.

Over 250 lightning flashes with definitive spectra were obtained in which 155 were of high quality. Because of the television system's capability to resolve individual strokes within a flash, the resulting number of quality spectra surpass 600. These data include not only ground strokes, but also a number of air discharges and step leaders. Comparisons with the work of the previous year show a remarkable improvement in the overall quality of these data including the number of detectable lines as well as improvements in the signal-to-noise ratio for individual features and the total spectra range covered by the system. Over 30 spectral features have been identified in the spectral region of 4000 - 8700 Å.

In order to analyze the video data a HP4895 desk top computer has been interfaced to an image memory, a digital tape drive, and a plotter. This allows computer control of nearly all aspects of the analysis procedures with a significant reduction in the time required to make spectral line scans of the data, a very important factor in regards to the large amount of data so far collected.

Airborne observations using a slit spectrograph with an ISIT vidicon detector, of cloud top lightning have also been conducted aboard a NASA Lear jet aircraft. Flights were conducted at 41000 feet altitude with cloud-top levels ranging from 37000 - 50000 feet. A quick-look analysis of the data indicate that over 50 flashes were recorded spectrally. In addition, the slit spectrograph was used from a ground-based observatory to make simultaneous observations with the slitless sytem.

CURRENT FOCUS OF RESEARCH WORK

The data obtained from the slit and slitless spectrographic cameras are currently being reduced. Emphasis for all data is placed on intracloud events, step leaders, spectral differences between strokes of a given flash, energy distribution along the vertical extent of a stroke, and temperature relationships to specific occurrences. Continual efforts are being made to upgrade the current data analysis capability and to further reduce the time required for spectral analysis in general.

PLANS FOR FY82

More effort will be placed in the simultaneous observation of lightning events with both slit and slitless spectrographs. The resulting data from both spectrographs will be mixed such that both images will be recorded simultaneously onto the same video frame. Both airborne and ground-based research are being considered for the coming year.

Title: Remote Observations of Severe Storms

Research Investigators: Dr. Richard E. Orville, ES214
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A. SIGNIFICANT ACCOMPLISHMENTS

1. Spectroscopic studies. The first absolute spectral irradiance measurements of the lightning flash have been obtained from the lower wavelength ozone cut-off at 280 nm to the near infrared limit of our detector at 900 nm. Many of these measurements have been made by using two spectrometers which give us a total wavelength coverage from 380 to 900 nm for the same lightning flash. These data identify the strongest emitter in lightning, which surprisingly is not H-alpha, but rather one or two neutral lines in the near infrared region. Approximately 1200 spectra obtained in 1981 in New Mexico are now being analyzed. Some of these spectra are from the same flashes observed by K. S. Clifton and K. Hill with NASA spectrometers.

2. Defense Meteorological Satellite Program. Under a cooperative program with the University of Wisconsin's Space Science and Engineering Center, we have received 365 consecutive days of midnight lightning data. Eighty per cent of these data have been digitized and entered into our UNIVAC computer. Monthly maps reveal significant variation of the lightning frequency, usually in agreement with changes in the global circulation. A preliminary report on this work has recently been published (Orville, 1981).

3. Simultaneous lightning location, satellite data, and radar displays. A cooperative study is in progress to overlay lightning ground strike data onto visible and IR satellite imagery. In addition, we are displaying the radar reflectivity data. The lightning data were obtained by M. Maier of Lightning Location and Protection, the radar data were supplied by D. Rust of NSSL-NOAA, and the satellite data have been provided by F. Mosher

and D. Wylie of SSEC-University of Wisconsin. Significant results of our April 10, 1979 study reveal that the ground strike locations are located in a small fraction of the total cloud cover, are usually associated with the coldest clouds, occur in the leading edge of the storm, and seem to be predominantly associated with the 30-40 dBz reflectivity region. Our research is continuing on other case studies.

B. CURRENT FOCUS OF RESEARCH WORK

Extend above accomplishments.

C. PLANS FOR FY-82

Measurements from above clouds correlated with ground measurements.

D. RECOMMENDATIONS FOR NEW RESEARCH

Expand measurements of lightning from U-2 aircraft and the Shuttle.

E. LIST OF PUBLICATIONS PREPARED SINCE JUNE 1980

1. Orville, R. E., "Global distribution of midnight lightning--September to November 1977", Monthly Weather Review, 109, No. 2, February 1981, 391-395.

2. Orville, R. E., "Lightning detection from space", CRC Press. Chapter in Handbook of Atmospherics, edited by H. Volland.

3. Idone, V., and R. E. Orville, "Lightning Return Stroke Velocity Measurements in TRIP", submitted to J. Geophys. Res.

4. Vonnegut, B., "The physics of thunderclouds", CRC Press. Chapter in Handbook of Atmospherics, edited by H. Volland.

R.F. LIGHTNING STUDIES AT MSFC

WAYNE WAGNON

The tasks undertaken at MSFC have been designed to support the following objectives: (1) evaluate the feasibility of using higher frequency (GHz range) for lightning detection from geosynchronous orbit, (2) validate and expand upon the spectral amplitude distribution, (3) assess the effects of man-made and natural background noise on signal detection, (4) characterize and better understand the discharge profile at the higher frequencies, and (5) evaluate various R.F. ground based detection techniques in support of a hybrid sensor system.

A study was conducted to assess the lightning and noise source characteristics, propagation effects imposed by the atmosphere and ionosphere and the electromagnetic environment in near space within which lightning R.F. signatures are to be detected. The results show that detection is feasible at the higher frequencies (1-10 GHz) especially if protected bands are used. Amplitudes on the order of 5 to 15 dB above the noise level should be possible. Received signals at these higher frequency ranges are more discrete (pulses) as contrasted to the nearly continuous radiation in the lower portion of the spectrum. Also, the hardware and systems needed are more compact and manageable in terms of implementation.

There is limited experimental data currently available to define and characterize the spectral amplitude distribution at the higher frequencies, especially above 1 GHz. Two efforts, one in-house and one at Auburn University, were undertaken to obtain additional data to better define the amplitude distributions as well as to investigate the data by high resolution techniques to determine the feasibility of characterization and to better understand the discharge phenomena in the GHz region. Detector systems were set up at several frequencies: 22.5 MHz, 225 MHz, 2.0 GHz, and 2.5 GHz. The measurements performed at the Marshall Center have been made at a center frequency of 2 GHz and a bandwidth of 4 MHz. Both horizontal and vertical polarization components are recorded. The data is sampled at a 20 Megabyte per second rate and stored as an eight bit word in a 128K word memory. This represents a record length of 6.4 milliseconds. A continuous analog record having a bandwidth of 40 KHz is made during the recording period. Synchronization pulses enable correlation of the two records. Limited data has been obtained and partially analyzed. The gathering of a larger data base and the analysis of obtained data continues. Results obtained to date are presented.

Diagrams of the existing systems and the planned expansions are defined. This includes all the measurements to obtain relative location and more accurate range information on recorded events. Additional data storage and computer capability are being added to further analyze and evaluate the data. The resulting system will be integrated with an HL interferometer system provided by Southwest Research.

R.F. And Optical Measurements of Lightning Emissions

Marx Brook

Research and Development Division

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Socorro, New Mexico 87801

An electric field-change meter and an optical sensor have been installed on a NASA U-2 aircraft for obtaining thunderstorm overflight lightning measurements. Additional measurements are made with a Fairchild line-scan camera and three 70 mm Vinton cameras for both spectral measurements of lightning and daytime and nighttime optical photographs of clouds and lightning.

A mobile van has been outfitted for ground-truth measurements. Instruments include an electric field-change meter and optical sensor similar to the U-2 instruments; a video camera; and six receivers covering the frequency range from 34.4 MHz to 2200 MHz. A wideband electric field-change meter provides coverage from D.C. to ≈2 MHz. Data are recorded on a 14 channel tape recorder recently furnished to us be NASA.

U-2 data were obtained over thunderstorms in Arkansas and Texas during the Spring of 1980; flights over the western U.S. (New Mexico, Arizona, Utah and Wyoming) are presently in progress (Spring and Summer, 1981). Some of the Arkansas data have been analyzed but final processing will be done on the new Sabre 80 tape recorder recently acquired.

Radiation data acquired with our receiver van during the present summer is substantial; the data include both natural and triggered lightning events from a number of different storms. The data look good from a cursory inspection, but no U-2 data flights over Langmuir Laboratory with simultaneous ground-truth data were obtained. Analysis of the data is in progress.

Plans for 1982 include making cooperative ground-truth measurements with the NSSL group at Norman during the Spring of 1982, if a U-2 aircraft can be used for overflights during the tornado season.

A paper describing some of our instrumentation was presented at the AIAA Sensor Systems Conference at Colorado Springs, Colorado, December 2-4, 1980.

Title: Storm Severity Detection (RF)

Research Investigator Involved:

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Significant Accomplishments FY-81

One objective of this study has been to investigate the use of electrical emissions (sferics) in long term forecasting of hurricane storm track. Sferic bursts are directionally resolved using a computer instrumented crossed baseline phase interferometer operating at 2 MHz with a 2.7 kHz bandwidth. Software has been developed to provide automatic data acquisition without an operator in attendance. The system detects a continental or oceanic storm in progress when sferic activity exceeds an empirically predetermined noise threshold and automatically logs azimuthally resolved sferic events to disc files. Sferic data have been analyzed for 1979 hurricanes Bob, Elena, Frederick and Henri. Also sferic data have been analyzed for the 1980 hurricane Allen. In the case of Bob, Elena, Frederick and Allen, the storms evidenced little or no electrical activity while over water; however, six to twelve hours prior to landfall, the storms exhibited a high degree of electrical activity in the right rear quadrant and in the feeder rain band. in the case of Henri which never came ashore, no significant enhancement in electrical activity was observed.

Current Focus of Research Work:

A computer instrumented crossed baseline interferometer is currently being fabricated for deployment at Marshall Space Flight Center. Seven crossed loop sensor elements have been obtained from surplus stock at the U.S. Army ECOM, New Jersey. The data acquisition electronics consisting of a Data General Nova 3/12, 10 MByte disc, display console, and dual channel receiver have been obtained commercially. Interface electronics to the computer are being fabricated by SwRI.

Plans for FY-82:

Time synchronized, directionally resolved sferic data between the direction finders at MSFC and SwRI, will be analyzed to provide location of the electrical activity in continental and oceanic thunderstorms as well as hurricanes. The location data will be compared with radar and satellite information to determine the relative proximity of intense convection and electrical activity. An assessment will be made to provide a short-term forecast of impending severe meteorological intensity.

Recommendations for New Research:

Based upon the results obtained to date, the following are recommended initiatives:

1. Deploy a third, phase linear sensor to permit triangulation and storm scale location based on phase linear electrical phenomena associated with severe meteorological activity.

2. Continue the present effort to study oceanic electrical storm data. In particular the area of hurricane monitoring could be extended to cover the Caribbean so that the formation phase of hurricane activity can be analyzed.

List of Publications Prepared since June 1980:

"Sferic Emissions Associated with Hurricane Activity During 1979 and 1980." (Manuscript to be submitted to the Journal of Geophysical Research)

TITLE: LIGHTNING CHARACTERISTICS AND ITS RELATIONSHIP TO STORM STRUCTURE

RESEARCH INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS FOR FY 81

The VHF lightning mapping sites co-located with NSSL's dual 10 cm Doppler radars were closely coordinated during our Spring Program 1981 severe storm observations. Dual mapping data were collected on ten severe storms and preliminary analysis indicates good data were obtained on six days--two of which contained tornadoes within 60 km of Norman. The VHF mapping instrumentation at Norman was modified to accommodate switching into a vertical looking mode for observing lightning overhead and extending down to 60° from the zenith.

Instrumentation for observing the ELF signals from lightning to examine the feasibility of utilizing these signals to detect cloud-to-ground strokes in a hybrid satellite system was designed and successfully tested.

Lightning echoes from 23 cm, L-band radar were simultaneously observed with the VHF space-time mapping of discharges for comparison and correlation. Range and time fluctuations of the L-band echoes were consistent with the lightning structure obtained from the VHF mapping data.

Intracloud lightning development continues to present a very complex picture as revealed by the VHF mapping technique. Long discharges, some in excess of 50 km in length generally progress at speeds between 5×10^4 and 3×10^5 $m \cdot s^{-1}$ and are located in the low reflectivity regions around or between storm centers. It is apparent that many of these long discharges are not comprised of a single interconnected flow of current made up of many channels and branches but are composed of several closely related discharges. Initiation of a component discharge may be delayed for several hundred milliseconds after the preceding discharge ceases to be active in that region.

Analysis was completed and a manuscript prepared on evaluating an electromagnetic technique for detecting tornadic storms. Results show that 82 percent (70 out of 85 tornadoes within 70 km) were detected using the burst rate observed at 3 MHz.

CURRENT FOCUS OF RESEARCH WORK

Data collected during the Spring Program 1981 have been checked for quality and archived. Some preliminary selection and analysis have been completed in preparation for future work with these data. We are presently engaged primarily in the analysis of data obtained on 19 June 1980 from four storms within 60 km of Norman.

PLANS FOR FY 82

We will continue to analyze data simultaneously obtained from our many severe storm sensors. We plan to continue developing new techniques, improving

our present array of sensors, expanding our data base, and addressing the fundamental questions concerning the role lightning plays in severe and nonsevere storms. Through our efforts at NSSL in the areas of lightning location mapping, the characterization of lightning parameters, and the determination of relationships in the co-evolving fields of winds, precipitation and lightning, we will help NASA develop techniques that will assist in forecasting, detecting, tracking and warning of weather hazards through the use of lightning observations.

RECOMMENDATIONS FOR NEW RESEARCH

Although we developed and tested new ELF instrumentation to detect cloud-to-ground strokes, determine polarity and estimate current flow, we did not have the wherewithal to bring the ELF technique into operation during our observational season. We propose to carry out the previously recommended ELF feasibility study.

We also propose to redesign the logic circuitry of the VHF mapping equipment so that we are no longer limited to selectable 60° azimuthal sectors but can record data simultaneously from all directions and at impulse rates to 64,000 per second.

LIST OF PUBLICATIONS PREPARED SINCE June 1980

"Tornadic Storm Detection Using an Electromagnetic Technique at Three Megahertz", William L. Taylor. J. Appl. Meteor., submitted for publication 1981.

Also see list of publications coauthored by Research Investigator presented under research activity title "Severe Storm Electricity".

In addition to the above refereed papers a number of reports, preprints, and presentations at scientific meetings have been authored or coauthored.

NASA/MSFC FY-81 Atmospheric Processes Research Review
prepared by

Roy T. Arnold, University of Mississippi

Title: Severe Storm Electricity via Storm Intercept

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Significant Accomplishments FY-81:

During the spring of 1981 we successfully operated the mobile laboratory near sixteen severe storms; on six occasions within 1 Km of a tornado. Slow and fast electric field changes, electric fields, 3 MHz spherics, lightning, optical transients, carona currents, TV records of lightning and cloud features, and both 35mm photographs and 16mm movies were acquired for severe storms within range of both dual and single Doppler (NSSL) radar. Except for a few isolated lightning flashes, it is too early for this data to have been analyzed.

In the spring of 1980, we successfully tracked eighteen severe storms five of which produced small tornadoes. During FY-81 we have analyzed some of the data on positive CG lightning and have completed a partial case history of a storm that was tracked for approximately three hours on 19 June 1980. Intercepted about 20 miles NW of Miami, TX around 1745 CST, this storm exhibited visually a banded inflow cloud flowing into the main tower from the east, massive towers on its flank, and striations on the sides and base of the main tower. A wall cloud was evident at 1755 CST and the mobile laboratory tracked with the wall cloud for an hour and twenty-five minutes. By 1830 CST, the wall cloud was rotating rapidly and the inflow winds were gusting to 40 knots. Wall cloud rotation decreased at 1835 CST but reintensified around 1900 CST. After about 1925 CST good visual contact with the storm's inflow region was lost. CG lightning activity appeared to diminish until the storm's demise.

The interesting point to note is that in the CG flash rate there are two peaks that can be definitively correlated with the visual cloud features. In the two instances just prior to the

intensification of wall cloud rotation, there was a marked increase in CG flash rate. In particular there were many short duration single stroke flashes which we have observed before to precede the wall cloud demise.

Unfortunately, there was no Doppler radar information available before 1859 CST and then it was single Doppler at very long range. Peaks in the flash rate data do show some correlation with peaks in the estimated cyclonic shear. However, the flash rate record is observationally biased because of obstructions in our field of view.

Current Focus of Research Work:

Our principal concern is to analyze the data we have acquired over four operational seasons. Specifically, we are trying to correlate lightning data with storm dynamics. We are, however, looking closely at the flash characteristics of both the short duration single stroke flashes and flashes that appear to transfer positive charge to ground.

Plans for FY-82:

Since we have been informed that NASA will no longer support field operation for the mobile lab we have no field operational plans for the spring of 1982.

Recommendations for New Research:

Although our principal immediate objective is to analyze data we have already acquired, there is still much to be done in the field. Measurements from the mobile lab are an asset to the understanding of severe storm electricity. Storm intercept has established the capability of producing good scientific results both qualitative and quantitative. We recommend extending the mobile laboratory work to include not only the current measurements but also some free balloon flights and some hail collection.

List of Publications Prepared since June 1980:

Other than an AGU Conference paper on the storm discussed above, there has been no publication of intercept accomplishments alone. However our observations have been an important part of the following papers:

1. W. David Rust, William T. Taylor, Donald R. MacGorman, and Roy T. Arnold, 1981: Research on Electrical Properties of Severe Thunderstorms on the Great Plains, (to appear in the September issue of Bull. of AMS).
2. W. David Rust, Donald R. MacGorman, and Roy T. Arnold, 1981: Positive Cloud to Ground Lightning Flashes in Severe Storms, (to appear in the July issue of GRL).

TITLE: SEVERE STORM ELECTRICITY

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SIGNIFICANT ACCOMPLISHMENTS FY 81

A. Data Acquisition

The 1981 Spring Program at NSSL again placed storm electricity as a top priority to support this NASA-sponsored research. NASA U2 overflight support included all mobile and fixed-site electrical and optical sensors, dual Doppler radar, and an air traffic controller stationed at NSSL.

A 4-station network was installed to locate (cloud-to-ground) CG strike points within about 300 km of NSSL and provide ground truth for NASA overflights. Two sites were operated (after modification by the manufacturer, Lightning Location and Protection, Inc.) as prototypes for location of +CG strike points.

Our mobile laboratory recorded electrical activity in severe storms and near several tornadoes (see R. Arnold report for details).

Radar observations of lightning included: lightning in the mesocyclone region of tornadic storms was observed with our 23-cm wavelength radar for a substantial portion of mesocyclone lifetime; regions of lightning activity were located and guidance information was provided to the NASA F106 aircraft which penetrated storms to measure lightning strikes to the aircraft.

During a squall line of severe and tornadic storms, many +CG flashes were documented to emanate from the back side (relative to line movement) of the line.

Electrical sensor systems at the Storm Electricity Building (SEB) were operated as in FY 80 with the addition of a second, high gain, fast antenna to record leader waveforms of CG flashes.

B. Data Analysis (since June 1980; details in listed publications)

1. +CG flashes

The occurrence of +CG flashes were verified to emanate from several regions of severe and tornadic storms: high on the back of the main storm tower, through the wall cloud, and from the downshear anvil.

Acoustic mapping of two +CG flashes shows thunder sources from +CG flashes as high as 15 km.

A typical field change from a slow antenna for +CG flashes shows a slow change prior to the abrupt return stroke that is followed by a larger, slow change indicative of continuing current.

2. Radar studies of lightning

The rise times of a lightning echo signal can be explained by propagation of the channel through the beam.

A technique has been developed to automatically extract lightning echoes from precipitation and ground clutter echoes.

Lightning density (flashes/min/km of range) has been determined for several storm cells and shows that that 'core' of lightning activity moves relative to the precipitation core during storm evolution. The lightning 'core' remains close to the leading edge of the precipitation core.

The horizontal extent of flashes increases with decreasing precipitation echo intensity (associated with storm decay).

Lightning propagates between individual cells in squall lines.

Our Doppler radar (10 cm) was used in a vertically pointing mode to determine the true vertical (radial) wind speed by using lightning echoes.

Doppler spectrum widths of lightning are usually less than those from precipitation and are <0.5 m/s.

Comparison of lightning echoes and VHF impulse source locations have been made (see also W. Taylor report).

3. Electrical and Doppler radar features of an isolated, super cell and tornadic storm, 19 June 1980

Lightning activity versus storm dynamics are inferred from a three-hour period of a tornadic storm, which was tracked with our mobile laboratory (see R. Arnold report for details).

CURRENT FOCUS OF RESEARCH WORK

. currently are concentrating on the analysis of storm electricity and dual Doppler radar measurements made on several severe storms of 19 June 1980, on the reduction of data obtained during 1981, and on the preparation of additional publications.

PLANS FOR FY 82

At this time, we anticipate continued joint research efforts between NASA and NSSL. This will include field operations again in Spring 82. We strongly urge a

continued, but expanded effort, to acquire data by overflights of severe storms. Without this we believe the testing of potential satellite-borne detectors is severely limited. This is, of course, particularly relevant to severe storm detection and observations from space. Analyses of data previously collected will continue.

RECOMMENDATIONS FOR NEW RESEARCH

Details of our recommended future research have been set forth in a proposal submitted to NASA in February 81. Fiscal and administrative constraints apparently necessitate substantial changes in that proposed research, and details of those changes are presently unavailable. It seems to us, however, that several of those proposed topics must be addressed for effective development and use of a satellite detector of lightning. They include: overflights of storms with various lightning detectors concurrent with ground-based measurements, pursuit of electrical indicators of severe storms, and development and evaluation of flash-type identification techniques suitable for use in a satellite system.

REFEREED PUBLICATIONS PREPARED SINCE JUNE 1980

"Research on Electrical Properties of Severe Thunderstorms on the Great Plains", W. David Rust, William L. Taylor, Donald R. MacGorman, and Roy T. Arnold. Bull. Amer. Meteor. Soc., to be published Sept. 1981.

"Positive Cloud-to-Ground Flashes in Severe Storms", W. David Rust, Donald R. MacGorman, and Roy T. Arnold. Geophys. Res. Lttr., to be published July 1981.

"Preliminary Study of Lightning Location Relative to Storm Structure", W. David Rust, William L. Taylor, and Don MacGorman. AIAA J., accepted for publication, 1981.

"Doppler Radar Echoes of Lightning and Precipitation at Vertical Incidence", Dusan S. Zrnic', W. David Rust, and William L. Taylor. J. Geophys. Res., submitted for publication, 1981.

In addition to these refereed papers, we have authored or coauthored with other NASA sponsored PI's, 16 articles and/or presentations for scientific meetings.

Title: Conceptual Design Study of Lightning Optical/Sensor Systems

Research Investigator(s) Involved: William L. Wolfe, Eustace L. Dereniak, Lang Brod, and Michael Nagler, Optical Sciences Center, University of Arizona, Tucson, Arizona 85721 (602) 626-3034

Significant Accomplishments FY-81: During the year starting September 1, 1980 and ending September 1, 1981 we have been concentrating on a flight experiment for a global lightning sensor. We completed the design study with some tradeoffs that showed the kinds of detector arrays that would be most useful. We have designed a telescope and a data handling system for US and for global coverage. The designs were necessarily limited by the paucity of data available on the amount and spectral distribution of lightning flux as seen from above. Accordingly we designed and built a dual sensor for use in a U-2 aircraft. The design was initiated about the first of the year and the instrument delivered to NASA on July 6. Results of the flights are reported elsewhere in this volume, we understand.

Current Focus of Research Work: Continuing work in this vein deals with refinement of the design, testing the data processing algorithms, building and testing the satellite optics and exploring the feasibility of filters for the tasks envisioned.

Plans for FY-82: We plan to analyze the results of the U-2 imaging and spectrometer flights to obtain data on the power and its distribution of a variety of lightning flashes. We will optimize the optical design for US viewing, consider alternate detector configurations to obtain the focal plane array necessary from existing components. We will investigate the feasibility of the required filters and the operation of the data processing algorithms.

Recommendations for New Research: We recommend the continuing studies discussed above as well as the obtaining of advanced CCD arrays so they can be investigated. It does not appear that new arrays need to be developed; other parts of NASA seem to be doing that.

List of Publications Prepared since June 1980:

Wolfe, W. L., and M. Nagler, "Conceptual design of a spaceborne lightning sensor," Presented at meeting SPIE, September 1980.

Wolfe, W. L., "A Global Lightning Sensor," Presented VIth International Conf. on Atmospheric Electricity, Manchester, England, July 1980.

Nagler, Michael, Design of a Spaceborne Lightning Sensor, Ph.D. dissertation, University of Arizona, Tucson, 1981.

TITLE: THEORY OF GLOBAL LIGHTNING AS SEEN FROM A SATELLITE

RESEARCH INVESTIGATOR: John T. A. Ely
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SIGNIFICANT ACCOMPLISHMENTS FY 81:

Finalized the data tape format specifications and completed the methods to be used in screening the tapes.

CURRENT FOCUS OF RESEARCH WORK:

Beginning the data processing, using the same superposition of epochs procedures used on the OV1-10 and OV1-86 satellite data that revealed the transient north-south asymmetries in the 1 Gev cosmic ray flux and their relationship to the "opening" of the magnetosphere.

PLANS FOR FY 82:

Complete the study of the correlations between these asymmetries and the three phenomena that may be strongly affected by megnetospheric transients: global lightning patterns, high latitude stratus cloud cover and SCATHA (Spacecraft Charging at High Altitudes).

TITLE: WARM CLOUD DEVELOPMENT STUDIES

RESEARCH INVESTIGATORS: B. J. Anderson
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SIGNIFICANT ACCOMPLISHMENTS FY 81:

The theoretical study of cloud droplet growth was completed during the latter part of 1980 and the results have been published as a NASA Technical Memo TM-82392. A modified version of that report has been accepted for publication in the Journal of Aerosol Science.

The major elements of the equipment pallet for the KC-135 experimental study of cloud drop growth were assembled during the summer of 1980. The system was first flown during September and the concept of the method was successfully verified. Following that flight an aerosol generation system and additional instrumentation were added. The system was flown again in April and May 1981. Good data sets were obtained during these flights. Data analysis is now in progress.

CURRENT FOCUS OF RESEARCH WORK:

This research effort is primarily directed toward the application of low gravity methods to the solution of selected problems in the microphysics of the formation and evolution of warm, ie., ice-free clouds. Specific tasks include a theoretical study of the growth and evaporation of individual cloud droplets (now completed) and an experimental study utilizing the KC-135 low gravity environment to determine the "sticking coefficient", the fraction of the impinging water molecules which stick to a droplet's surface. Currently, the major effort centers on the analysis of data from the April and May KC-135 flights. This work includes both numerical analysis and laboratory testing of the hardware performance.

In addition, an effort to devise methods to investigate the impact of phoretic forces on the scavenging of large aerosol particles by cloud drops has been undertaken. Phoretic forces are forces which arise due to the temperature and composition gradients around growing and evaporating drops. This scavenging mechanism is believed to be one of the dominant removal methods for particulates in the 0.1 to 1 micron range. Thus, knowledge of this scavenging efficiency is important for projecting the lifetime and optical characteristics of various artificial pollution sources, urban "smog" for example, and for analysis of the evolution of the aerosol size distribution in the Shuttle exhaust cloud. Several experimental strategies for the investigation of this problem are under onsideration.

PLANS FOR FY 82:

After completion of the analysis of the existing droplet growth data, it is expected that some minor improvements to the hardware and one additional flight experiment will yield a verification of the cloud formation theory (the numerical model) and a single temperature determination of the sticking coefficient. A study was successfully proposed to the Materials Processing in Space Program for a more sophisticated experiment using the same basic methods to measure the variation of the sticking coefficient with temperature. A complementary experimental study of the efficiency of the phoretic scavenging mechanism will be undertaken.

RECOMMENDATIONS FOR FOLLOW-ON RESEARCH:

Fruitful theoretical research could be undertaken on both the mechanism of the phoretic scavenging process and on the role it plays in the evolution of the Shuttle exhaust cloud which contains high concentrations of particulates in the 0.1 to 1 micron size range.

PUBLICATIONS:

"An Extended Classical Solution of the Droplet Growth Problem" by B. Jeffrey Anderson, John Hallett, and Maurice Beesley. NASA TM-82392, January 1981. (Condensed version to appear in the Journal of Aerosol Science.)

TITLE: COLD CLOUD STUDIES

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SIGNIFICANT ACCOMPLISHMENTS FY 81:

An ice crystal growth from liquid experiment which utilizes Moire fringe optics to detect convection around the growing crystals was successfully flown on KC-135 low gravity flights during both April and May, 1981. Although laboratory studies with this system readily reveal convection in growth from solution, even at small supercoolings (~0.5 C), convection in low gravity was less than the detection threshold of the system. This was even true at higher supercooling (~2.0 C) where density gradients are larger and convection effects should be more easily observed.

The static thermal diffusion chamber which was designed and constructed as a part of the Severe Storms RTOP is now operational. The data acquisition and control software for the microprocessor controlled system has been written and debugged. Laboratory experiments are now in progress.

A second diffusion chamber constructed by Desert Research Institute after the design of our chamber has been incorporated into a KC-135 experiment package and is scheduled to fly low gravity parabolas during August 1981. The plates on this chamber are cooled with thermoelectric modules (TEMs) to eliminate the need for refrigerated bath circulators aboard the KC-135 aircraft. Data acquisition and control is via a microprocessor system. This experiment package will be used to investigate unattached droplet freezing in low gravity and the likelihood of "ice multiplication" by production of "splinter" particles during the freezing process. Ice crystal nucleation and growth from the vapor phase will also be investigated. These experiments were originally developed for the Shuttle/ACPL Program. They are now being studied in more detail to establish the most feasible and useful experiments for future Shuttle flights. Continuation of the experiments in conjunction with Dr. John Hallett of the University of Nevada-Reno and Dr. Clive Saunders of the University of Manchester, U.K. is through the Materials Processing in Space Program.

Computer software has been written and documented to perform the necessary reduction and graphical presentation of the laboratory ice multiplication experiment data which is recorded on magnetic cassette tape. The software was written for the Space Sciences Laboratory's REEDA Hewlett Packard (HP-1000) minicomputer system and is general enough that it can be used for data reduction of compatible tapes from other experiments.

CURRENT FOCUS OF RESEARCH WORK:

Laboratory studies of ice crystal growth from the vapor in a static diffusion chamber are now being emphasized. Study of the ice multiplication process is also being continued even though difficulties with the experimental apparatus have made progress slow in this area. Other tasks include experimental studies utilizing the low gravity environment available with the KC-135 aircraft to evaluate the effect of reduced convection on ice crystal growth rate and habit and to examine the water to ice phase transition.

Although these studies primarily involve basic research on ice crystal growth, the results can be applied to systems as diverse as crystal growth theory, sea ice formation, cryogenics, and cloud glaciation (the water to ice phase transition with associated "ice multiplication" effects which can substantially influence the growth of cumuliform clouds through release of latent heat). The mechanics of ice nucleation and multiplication also relate to the possibility of inadvertent weather modification by the Shuttle exhaust cloud.

PLANS FOR FY 82:

Our projected plan of study for FY-82 within the cold cloud area places special emphasis on the static thermal diffusion chamber experiments with work on the ice multiplication problem continuing at a low level of effort. Specific laboratory tasks include:

1. A detailed examination of ice crystal growth rates and habit changes in a controlled temperature, pressure, and supersaturation environment as a function of-
   a. The thermal diffusivity of the carrier gas
   b. The water vapor diffusivity of the carrier gas
   c. Gaseous organic contaminants
   d. An applied electric field

2. An examination of ice crystal production rate as a function of the cloud particle properties, (i.e., surface characteristics, size spectrum, and concentration).

As a follow-up to the FY 81 KC-135 experiments, the system optics for the ice crystal growth from the liquid study are being upgraded as part of another program to provide greater sensitivity. As part of that program, which is an outgrowth of the Severe Storm sponsored work, the more sensitive system will be used to investigate the effect of reduced convection on the anomalous growth of ice crystals in dilute (.5% to 10%) NaCl solution.

RECOMMENDATIONS FOR FOLLOW-ON RESEARCH:

Additional research on the role of electrical charge transfer in the ice multiplication process could prove very beneficial to both cloud physics and to the study of atmospheric electricity. However, this is a difficult area

of investigation and progress may prove to be slow.

PUBLICATIONS:

NASA CR-161663, Feb. 1981, "A Statistical Data Analysis and Plotting Program for Cloud Microphysics Experiments" by A. J. Jordan, ESPEE, Inc., Huntsville, Alabama, 141 pp.

The Quarterly Journal of the Royal Meteorological Society, July 1981, Vol. 107, No. 453, "Microphysical Development of A Pulsating Cumulus Tower: A Case Study", by V. W. Keller and R. I. Sax, pp. 678-697.

Ready for submission to the Journal of Crystal Growth, "Influence of Air Velocity on the Habit of Ice Crystal Growth from the Vapor", by V. W. Keller and J. Hallett.

CLOUD CONDENSATION NUCLEI WORKSHOP

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B. Significant Accomplishments in FY-81

The International Workshop was organized and conducted with DRI host to 39 participants representing 20 institutions. Twenty-two instruments were present for 29 experiments. Results are to be published in abridged form in *Journal de Recherches Atmospheriques*, and in complete form in a Proceedings volume. Publication effort is nearing completion.

C. Current Focus of Research Work

Not applicable to this completed effort

D. Plans for FY-82

Complete final preparation of Proceedings volume.

E. Recommendations for New Research

1. Consider maintaining DRI Workshop facility as permanent aerosol calibration laboratory.
2. Encourage support of a similar Workshop within the next 3-5 years.

F. List of Publications Prepared Since June 1980

1. A Proceedings volume containing the complete data base and writeups by all participants is being prepared.
2. The six following papers authored or co-authored by DRI personnel have been accepted for publication in *Journal de Recherches Atmospheriques*. There are 18 other papers resulting from the Workshop which will appear at the same time in this Journal, under the authorship of participants from other institutions.
   a. Fitzgerald, J.W., and C.F. Rogers, 1981: Review of isothermal haze chamber performance.
   b. Hudson, J.G., and D.J. Alofs, 1981: performance of the continuous flow diffusion chambers.
   c. Hudson, J.G., C.F. Rogers, and G. Keyser, 1981: Three CCN counters and an isothermal haze chamber operated at the 1980 International CCN Workshop.

d. Katz, U., and J.Y. Dea, 1981: Aerosol generation and distribution system for the Third International CCN Workshop.

e. Dea, J.Y., and U. Katz, 1981: Steady generation of aerosol with an improved constant output atomizer.

f. Rogers, C.F., and R.L. McKenzie, 1981: Comparisons of two Aitken counters with cloud condensation nuclei counters at the 1980 International CCN Workshop.

ACPL CLOUD-FORMING EXPERIMENT

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B. Significant Accomplishments in FY-81

1. Completion of Scott-Robinson first-principles kinetic theory of cloud droplet growth by condensation.
2. Completion of 31 experiments in ground-based cloud-forming experiment, utilizing DRI expansion chamber and instantaneous cloud condensation nuclei (CCN) spectrometer (results currently being analyzed).
3. Initiation of a study of the relative roles of CCN and mixing in shaping of cloud droplet size spectra.

C. Current Focus of Research Work

1. Complete the analysis of results of ground-based cloud-forming experiment. General indications are that experimental method is successful.
2. Complete study of relative roles of CCN, mixing, in cloud droplet spectra.
3. Complete the design of a new airborne CCN spectrometer and begin construction.

D. Plans for FY-82

In view of program funding restrictions and cancellation of the ACPL flight facility, it is difficult to provide a concise response to this item. The Investigators will evaluate the likelihood of continued support for the Cloud-Forming Experiment as it proceeds toward the next step, performance in either low-g or the earth's atmosphere.

E. Recommendations for New Research

1. Perform Cloud-Forming Experiment in low-g and/or a mountain wave cloud in the earth's atmosphere.
2. Continue tropospheric investigations of CCN and their importance to cloud and precipitation development.

F. List of Publications Prepared Since June 1980

1. Hudson, J.G., G. Keyser, and C.F. Rogers, 1980: Two new CCN spectrometers. Proceedings, International Cloud Physics Conference, July 15-19, 1980. Clermont-Ferrand, France.

2. Robinson, N.F., and W.T. Scott, 1981: Two-stream Maxwellian kinetic theory of cloud droplet growth by condensation. *J. Atmos. Sci., 38*, 1015-1026.

3. Robinson, N.F., 1981: Numerical simulation of non-steady-state droplet growth (In preparation).

4. Results of the ground-based cloud-forming experiment will be prepared for publication.

COMPLEX AEROSOL NUCLEATION EXPERIMENT

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B. Significant Accomplishments in FY-81

1. Completed study of published accounts of surface porosity as a cause of slow adsorption of water vapor.
2. Completed experimental study of water vapor nucleation of coal combustion fly ash aerosol.

C. Current Focus of Research Work

Continue to investigate slow or delayed nucleation phenomena reported for aerosols such as waxes, silver iodide, and coal combustion fly ash.

D. Plans for FY-82

Continue studies of nucleation on materials of limited wettability. Consider seeking support for delayed nucleation studies in low-g.

E. Recommendations for New Research

1. Compare cloud chamber nucleation method to older adsorption measurements methods.
2. Evaluate real atmospheric nuclei in terms of adsorption and nucleation rates.

F. List of Publications Prepared Since June 1980

Rogers, C.F., J.G. Hudson, and W.C. Kocmond, 1981: Measurements with an instantaneous CCN spectrometer. Accepted for presentation at the Symposium on Nucleation (Tenth International Nucleation Conference) at the IAMAP General Assembly, 17-28 August, 1981, Hamburg, Germany. (Paper summarizes coal fly ash results).

TITLE: A COMPARATIVE STUDY OF THE TRACKING PRECISION OF THE RAWINSONDE SYSTEM USED IN MESOSCALE AND GROUND TRUTH EXPERIMENTS

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SIGNIFICANT ACCOMPLISHMENTS FY81:

During FY 81, a series of tests with up to 12 GMD-1 units were used to track a single radiosonde. The purpose of this test was to evaluate the precision of the tracking system. Results of the preliminary tracking tests have been used to develop estimates of the RMS wind velocity errors in the upper level wind data acquired during the AVE and AVE-SESAME time periods. Among the preliminary findings are that:

1) Tracking precision is a function of rate of antenna motion. RMS tracking precision is on the order of a few tenths of a degree for antenna motion rates of a few degrees per minute. At very slow antenna motion rates, the precision approaches the 0.05 deg. often quoted as system accuracy. Rapid antenna motion rates occur when the sounding balloon is at low heights. Slow antenna motion rates take place at heights near the tropopause.

2) A parametric analysis of the wind velocity error has been carried out using the preliminary precision data in the MSFC tests. This analysis indicates that the RMS wind errors increase with height and that at a given height, decrease as the antenna elevation angles increase. The magnitude of the RMS vector wind error ranges from 1 m/s at 850 mb to 8 m/s at 200 mb using the antenna elevation data from the AVE-SESAME I case. The analysis shows that the wind speed and direction errors are a function of the azimuth of the balloon relative to the tracking antenna and the wind velocity at the wind level in question.

3) Tracking antenna statistics were compiled as to elevation angle and the change of angular position of the sounding system per unit time in the first three AVE-SESAME cases. Means and distribution characteristics have been tabulated as a function of pressure level for both future parametric analysis of the error distributions and specific error studies in the AVE-SESAME data.

CURRENT FOCUS OF RESEARCH:

Current research efforts are centered about the expansion of the data base from which the tracking precision values were determined. Earlier tests were taken under relatively strong wind conditions with corresponding low elevation angles.

A series of late summer-early fall tracking tests will make use of the normally low tropospheric wind speeds to determine the tracking precision when the antenna elevation angles are high at the time the balloon is in the upper troposphere.

PLANS FOR FY 82:

The next phase of this study will be to combine tracking precision data from a range of environmental conditions leading to different balloon elevation angles and antenna elevation change rates. This data will be used to develop a comprehensive error analysis for the RAWINSONDE data as used in the AVE-SESAME cases. Tests will also be made to evaluate the inter set variability of thermodynamic parameters using one sensor/transmitter system with several GMD systems.

RECOMMENDATIONS FOR NEW RESEARCH:

After the tracking precision and precision in thermodynamic variables have been determined, tests for small scale spatial variability should be undertaken. This study should be designed to determine the upper level spatial variability over distances from a few hundred meters to a few kilometers .

PUBLICATIONS:

Upper Level Wind Errors Inherent in the AVE-SESAME I Data, Abstracts of Proceedings at the SESAME Preliminary Results Workshop, Huntsville, Alabama, March 24-25, 1979.

A comparative error analysis of upper level winds measured by the Jimsphere/FPS-16, the Meteorological Sounding System (MSS) and the Windsonde/GMD-4 Sounding System, minutes of the RCC/MG, August 1981.

TITLE: SATELLITE-INFRARED, RAWINSONDE AND GRAVITY WAVE STUDY OF SEVERE CONVECTIVE STORMS

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Significant Accomplishments FY-81:

Several cases of GOES digital infrared data and Doppler sounder array data during the three-hour time period immediately preceding the touchdown of the tornado were analyzed. Tornado-associated clouds are compared with non-tornado-associated clouds using satellite infrared data, ray tracing of gravity waves detected by the Doppler sounder array, and rawinsonde data. The satellite observations are at 15 minute intervals. Satellite picture intervals longer than 15 minutes are of limited use for severe storm analysis because information on the collapse of the penetrative cloud top in the 15 to 30 minutes before the tornado touchdown may be missing.

Our study shows the following:

(1) Tornado-associated clouds are always accompanied by overshooting turrets penetrating above the tropopause.

(2) The difference between the overshooting cloud top temperature and the tropopause temperature, a measure of how much the cloud has penetrated above the tropopause, rather than either the absolute temperature of the penetrative cloud or the height of the top of overshooting turret is significant for the possible formation of severe storms.

(3) The growth rate of the overshooting turret above the tropopause for severe storm-associated clouds is much greater than that of non-severe storm-associated clouds.

(4) The size of the area of overshooting turret above the tropopause for the cloud associated with a severe storm is on the order of several hundred pixels observed from geosynchronous satellite. In other words, a high cloud with a small size overshooting turret (less than 150 pixels) above the tropopause appears to be hard to convert into a tornadic cloud.

(5) The high density penetrative overshooting turret (temperature of the overshooting turret is much colder than the surrounding air temperature) above the tropopause begins to collapse about 15 to 30 minutes before the tornado touchdown.

(6) The life of a tornado-associated cloud, from the moment the overshooting turret penetrates above the tropopause to the touchdown of the tornado, is no more than 3 hours.

(7) Gravity waves are always observed when there are severe convective storms. Ray tracing results show that the source of these gravity waves is located at the cloud with intensive convection at the time the overshooting turret of the cloud is penetrating above the tropopuase.

By combining the results obtained from cloud top temperature changes from satellite infrared imagery, the altitude-temperature relationship from rawinsonde data, and the Doppler sounder gravity wave observations, one can show a series of time steps for the evolution of a tornadic cloud from a thundercloud. A cumulonimbus cloud with intense convection creates an overshooting turret penetrating above the tropopause. A group of gravity wave trains are detected at ionospheric height during this time period. In general, the cloud top penetrates about 3 to 6 km above the tropopause. Since the overshooting top temperature is much lower than the surrounding air, the density of the overshooting turret is much higher than the density of the surrounding air. Therefore, the overshooting turret can only exist as long as it is dynamically supported by intensive vertical convection. When the intense vertical convection can no longer support the mass of the overshooting turret, it collapses. This occurs about 15 to 30 minutes before the touchdown of the tornado. The collapsing of the overshooting turret creates the funnel cloud under the cloud base and the tornado finally touches down.

These results are based on a number of case studies. Needless to say, further studies are required with additional data sets before more definite conclusions can be reached.

Current Focus of Research Work:

GOES digital infrared data of severe storms in southeastern Arkansas, and on the Arkansas and Tennessee border on April 11, 1976 are currently being analyzed. The purpose of the study is to further confirm our preliminary results of how a convective cloud becomes a tornado.

Our current focus is to analyze the available rapid scan digital infrared data for severe storms in which the computation of the gravity wave ray tracings have already been accomplished. These dates include August 5, 1975; January 13, 1976; January 25, 1976, and others. We have requested the GOES digital data for the above time periods; however, to date we have not received the complete set of these data.

Plans for FY-82:

Investigation of the characteristics of the evolution of severe thunderclouds before the formation of tornadoes based on AVE-SESAME data, GOES infrared imagery, radar data, and gravity waves from Doppler sounder records is planned.

In particular, we are going to analyze and compare cloud top temperature distributions with tropopause temperatures, and rates of change of temperatures of clouds associated with and without tornadoes, and also the gravity wave triggering mechanism which leads to the formation of tornadoes.

Recommendations for New Research:

The association of gravity waves with the initiation of tornadic storms suggests that a study of the critical buoyancy frequency and moisture content during the period immediately prior to and at the time of excitation of gravity waves may lead to a technique for the early detection of severe convective storms. AVE-SESAME meteorological data will be analyzed to determine if there is critical oscillation frequency and moisture content in those situations which culminate in tornadic storms. Also satellite infrared imagery will be used to analyze the development of tornadic storms from the penetration and collapsing of overshooting turrets.

List of Publications Prepared Since June 1980:

(1) Hung, R.J., T. Phan, D.C. Lin, R.E. Smith, R.R. Jayroe, and G.S. West, Gravity Waves and GOES IR data study of an isolated tornadic storm on 29 May 1977, Mont. Weath. Rev., 108, 456-464, 1980.

(2) Hung, R.J., and R.E. Smith, Ionospheric remote sensing of medium scale gravity waves and tornadic storms, Il Nuovo Cimento, (in press), 1981.

(3) Hung, R.J., and R.E. Smith, GOES infrared study of tornadic storms, Proc. on Remote Sensing of Environment, pp. 1621-1629, Environmental Research Institute of Michigan, 1980.

(4) Hung, R.J., and R.E. Smith, Remote sensing of tornadic storms based on HF radio wave from ionosphere and IR imagery from GOES satellite, Proc. North Amer. Union of Radio Sci., pp. 239, Univ. Laval, Quebec, Canada, 1980.

(5) Hung, R.J., and R.E. Smith, Severe convective storm study based on the analysis of penetrative overshooting clouds from satellite infrared data, EOS, 62, 293, 1981.

(6) Hung, R.J., and R.E. Smith, Infrared digital data analysis of severe storms from geosynchronous satellite, Proc. Internt. Symp. Remote Sens. of Environt., pp. 57, 1981.

(7) Hung, R.J., and R.E. Smith, Remote sensing of convective storms from geosynchronous satellite infrared digital data, submitted to Int. J. Remote Sensing, 1981.

(8) Hung, R.J., and R.E. Smith, Case study of March 24, 1976, Louisiana tornado by using Doppler sounder, satellite infrared imagery and balloon observations, submitted to J. Geophys. Res., 1981.

OUTLINE OF RESEARCH ACTIVITIES

Title: Acoustic and Gravity Waves in the Neutral Atmosphere and the Ionosphere Generated by Severe Storms

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Significant Accomplishments FY-81:

Gravity waves generated by intense thunderstorms have been detected by ground-level pressure sensors. These waves apparently triggered new thunderstorms under proper temperature and humidity conditions.

Infrasonic waves apparently associated with the sudden collapse of the electrostatic field have been recorded. The confirmation of the source of the signal is made with the use of electric field measurements as well as recordings of audible thunder.

Gravity waves at ionospheric levels associated with storms have been detected by our Doppler-sounder array. The waves seem to be arriving from the upper-air low pressure center of the storm.

Current Focus of Research Work

The current focus is on recording and analyzing disturbances at ionospheric levels generated by severe storms. The objective is to learn about the relationship of gravity waves at ionospheric levels to the intensity and movement of severe storms. Particular emphasis will be on the connection of gravity waves with tornadic storms. Theoretical work on the generation of gravity waves by severe storms is also an important objective.

Further studies of infrasound associated with lightning, viz., to determine the relationship of infrasound to different kinds of discharges is also being pursued.

Plans for FY-82:

In FY-82 the main emphasis will be on the experimental and theoretical studies of gravity waves in the ionosphere. Faraday rotation measurements of radio beacons from a satellite in order to study gravity waves in the ionosphere will be undertaken.

Recommendations for New Research:

The ionospheric gravity wave study in conjunction with Doppler radar studies of severe storms will be very useful.

List of Publications:

1. Balachandran, N.K., 1980: Gravity waves from thunderstorms, Mon. Wea. Rev., 108, 804-816.

2. Balachandran, N.K., Low-frequency sound associated with lightning discharges; Proceedings of the VIth International Conference on Atmospheric Electricity (In Press).

3. Donn, W.L. and N.K. Balachandran, 1981: Mount St. Helens Eruptions of 18 May 1980: Air waves and explosive yield; Science, 213, 539-541.

TITLE: ANALYSIS OF SATELLITE DATA FOR SENSOR IMPROVEMENT

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Significant Accomplishments for FY-81

The major subject being investigated under the current grant is to establish the relationship between (1) cloud-top features and (2) storm characteristics on the earth. Item (1) involves infrared mapping of the cloud-top temperature and stereoscopic computations of cloud-top heights. IR mapping of the SESAME-DAY thunderstorms was completed. An abstract of a paper to be presented before the Nowcasting Symposium at Humburg, Germany is shown at the end.

Item (2) was investigated intensively during the 1970s, reaching the conclusion that local windstorms are classified into tornadoes and downbursts. Abstracts of two papers to be published in Monthly Weather Review and Journal of Atmospheric Sciences are presented at the end.

Current Focus of Research Work

Computer method of obtaining stereoscopic cloud heights from GOES West and East as well as GOES West and Japanese Geosynchronous Satellite has been worked out. Through this method, cloud heights can be computed with 0.2 km accuracy.

It is expected that this result can be applied to the mesurement of cloud heights over the Pacific as well as those over the Midwest. The accuracy over the ocean measurements has been improved for direct application to the near-the-edge measurements.

Plans for FY-82

The cloud-top vs terrestrial storm relationships will be investigated further with specific emphasis on

a. Effects of stratospheric cirrus clouds on IR temperature measurements and

b. Stereo-height measurements of severe storm clouds over the Midwest and ITCZ and typhoon clouds over the Pacific. This will be a part of the NASA-JAPAN cooperative program.

Abstracts of Published Papers in FY-81

Titles and abstracts are presented. Full papers are available from the author upon request.

No.1 To be presented at the Nowcasting Symposium, August, 1981 at Humburg

Mesoscale Aspects of Convective Storms

By T. Theodore Fujita

Abstract

The term "mesoscale" has been in use for the past 30 years, being defined rather loosely. Now the generalized mesoscale, applicable to terrestrial disturbances, was defined to extend between 4 km and 400 km through two orders of magnitude in horizontal dimensions. Recent studies revealec that mesoscale disturbances often induce strong winds, but their windspeeds are significantly less than those accompanied by sub-mesoscale storms such as tornado, downburst, and microburst. It was concluded that very accurate combination of radar and satellite measurements hold the key in nowcasting the nature of mesoscale clouds, the inducers of severe local wind and rain storms.

Keywords: Planetary mesoscale, Mesocyclone, Tornado, Downburst, Microburst, Severe storm wake, GOES East and West, Flash flood.

No.2 To be published in July Issue of Monthly Weather Review

Five Scales of Airflow Associated with a Series of Downbursts on 16 July 1980

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(Manuscript received 5 September 1980, in final form 17 March 1981)

ABSTRACT

A series of destructive windstorms on 16 July 1980 in a 50 km (30 mi) wide zone from Chicago to Detroit was surveyed both from the air and the ground. In spite of the initial suspicion of 10–20 tornadoes in the area, the nature of the windstorms was confirmed to be downbursts and microbursts characterized by multiple scales of airflows with their horizontal dimensions extending tens of meters to hundreds of kilometers.

An attempt was made to estimate the wind speed based on three types of airborne objects: a 180 kg (390 lb) chimney, a 1000 kg (one ton) corn storage bin, and lumber from damaged roofs found inside downburst areas, obtaining the maximum wind speed of 63 ± 10 m s^{-1} (140 ± 25 mph). A total of 5500 million damage reported was caused by thunderstorm-induced non-tornadic storms which affected very large areas.

SMS/GOES pictures showed that the parent cloud was oval-shaped with its lifetime in excess of 12 h. The overshooting areas enclosed by the −66°C isotherms shrunk rapidly at the onset of the Chicago-area downbursts, indicating that the downbursts began when overshooting activities subsided. This variation of the overshooting features, however, does not necessarily imply a direct physical link between the collapsing top and the downbursts at the surface. This paper presents cloud-top features and wind effects on the ground with no attempt to relate them on the basis of conceptual models currently available.

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Tornadoes and Downbursts in the Context of Generalized Planetary Scales

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(Manuscript received 24 December 1980, in final form 2 February 1981)

ABSTRACT

In order to cover a wide range of horizontal dimensions of airflow, the author proposes a series of five scales, maso, meso, miso (to be read as my-so), moso and muso arranged in the order of the vowels, A, E, I, O, U. The dimensions decrease by two orders of magnitude per scale, beginning with the planet's equator length chosen to be the maximum dimension of masoscale.

Mesoscale highs and lows were described on the bases of mesoanalyses, while sub-mesoscale disturbances were depicted by cataloging over 20 000 photographs of wind effects taken from low-flying aircraft during the past 15 years. Various motion thus classified into these scales led to a conclusion that extreme winds induced by thunderstorms are associated with misoscale and mososcale airflow spawned by the parent, mesoscale disturbances.

TITLE: STRUCTURE AND DYNAMICS OF THE SEVERE STORM ENVIRONMENT: A COMPARISON BETWEEN RAWINSONDE AND SATELLITE-DERIVED DATA

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SIGNIFICANT ACCOMPLISHMENTS FY 81:

Atmospheric sounding data from the polar orbiting TIROS-N weather satellite have been obtained by the AVE-SESAME I experiment. These data consist of regional scale temperature and moisture profiles at mandatory pressure levels which were produced with Man Computer Interactive Data Access System (McIDAS) processing by the NESS group at the University of Wisconsin. Gradient thermal winds and balance winds were computed from the sounding data and serve to supplement the satellite data set. These soundings, despite their limited vertical resolution, have a superior spatial resolution compared to conventional synoptic scale rawinsonde measurements.

In order to evaluate how well these data describe the structure of the severe storm environment, the soundings were made to look like 25 mb rawinsonde data from the AVE-SESAME experiment. This was done by first computing basic meteorological parameters from the original satellite data at mandatory pressure levels. The basic parameters were then interpolated in the vertical to produce data at 25 mb increments from the surface to 100 mb. These data have been put on disk to be analyzed by Mesoscale and Severe Storms (MASS) computer at Marshall Space Flight Center.

CURRENT FOCUS OF RESEARCH:

Current efforts are directed towards producing gridded fields of meteorological parameters using the satellite derived 25 mb sounding data. Parameters such as divergence, vertical motion, geopotential height, and various advection quantities (eg., vorticity, advection and moisture advection) along with the basic parameters can be used to describe the 3-dimensional strucure of the atmosphere. Similar techniques are being used on both the satellite and rawinsonde data so that valid comparisons can be made between the two data sets.

PLANS FOR FY 82:

Since this research project was just recently started, the major analysis will be conducted during the FY 82. The researcher's familiarity with the rawinsonde data from the particular storm case under investigation will aid considerably in the evaluation of the satellite sounding data. Particular differences between the two types of data will be evaluated for their meteorological significance and conclusions will be presented based on these differences. An extended evaluation of the data may include other diagnostic computations for stability and energy budget analysis. This would be in the area of the researcher's past area of experience. A logical follow-up to this work would be a similar evaluation of sounding data taken from the VAS instrument now being tested.

RECOMMENDATIONS FOR NEW RESEARCH:

The key to a successful mesoscale meteorological analysis is to utilize data which capture a given phenomenon under investigation. The lack of such data has hampered research in the area of severe local storms. An important step to overcome this problem is the application of space sensors to produce atmospheric soundings with improved space and time resolution. With this data b coming more readily available, new theories can be developed and tested which will lead to a better understanding of the weather and increased predictability. Preliminary analysis of satellite sounding data are encouraging and efforts should be continued to develop and refine the retrieval techniques. A major obstacle which faces the user community is the successful integration of satellite sounding data and rawinsonde data. The two types of vertical profile information have inherent differences in that they actually measure as well as biases which needed not be the same for each sensor. Further investigation is needed to evaluate the data as well as the error the measurements contain before they can be successfully combined to achieve the high resolution data the mesoscale meteorologist needs.

PUBLICATIONS:

Jedlovec, Gary J. and Henry E. Fuelberg, 1981: A Subsynoptic-Scale Kinetic Energy Study of the Red River Valley Tornado Outbreak. Interim Rept., Contract NAS8-33370, submitted for publication in June.

TITLE: MESOSCALE STORM ANALYSIS AND INTERPRETATION UTILIZING THE McIDAS SYSTEM

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SIGNIFICANT ACCOMPLISHMENTS FY 81:

A McIDAS terminal was installed in April at Marshall Space Flight Center as a tool to evaluate severe storms and local weather events. Several months were allocated for the investigators to become acquainted with the system, its file structure and data base management, and to further evaluate its potential for synthesizing various types of meteorological data. It was soon realized that the system performed well and would meet all the requirements set forth to analyze data from space sensors in combination with conventional meteorological data. McIDAS also proved to be extremely valuable in making quantified image calculations and for the evaluation of VAS imagery and sounding data.

CURRENT FOCUS OF RESEARCH WORK:

The overall objective of the McIDAS research program is to utilize available data resources for an investigation of mesoscale meteorological phenomena. Data from special experiments conducted by NASA are extremely valuable in this task because they provide measurements with improved time and space resolution of the atmosphere during storm periods. Current research efforts utilize the vast capabilities of McIDAS to analyze these special data sets.

An important aspect of McIDAS which allows for a detailed analysis of storms is its interactive capability. This allows the user to combine display, and overlay many meteorological parameters at his own discretion in order to better evaluate the significance of the data.

A second major feature of McIDAS is the ability to work with the image data in digital form. This allows the McIDAS user to study the changes in features observed in satellite images in a quantified manner and relate them to changes in other meteorological parameters. The importance of this is that satellites routinely provide data having resolution superior to that of conventional data. Used in conjunction with McIDAS, these measurements provide a unique opportunity for the mesoscale researcher to advance his knowledge of the mesoscale environment.

PLANS FOR FY 82:

Future research plans involving McIDAS will continue to incorporate special

rawinsonde data as well as satellite imagery to investigate severe storm occurrences. A Major emphasis will also be placed on the evaluation and usage of VAS imagery and sounding data which is becoming more readily available. Image data in the CO_2 and water vapor spectral bands should provide new information on the amounts of each substance and its global concentration. Data from special data collection periods will be compared to fine resolution rawinsonde data to determine the quality of the satellite soundings.

With the McIDAS user community increasing in size, the system could allow for work in the area of technique development and technology transfer. New forecasting models and techniques could be developed and tested operationally, using McIDAS to eventually improve our severe storm prediction capabilities.

TITLE: AUTOMATED MESOSCALE WINDS DETERMINED FROM GOES SATELLITE IMAGERY AND AVE/SESAME/VAS DATA

RESEARCH INVESTIGATORS: Gregory S. Wilson/ES84
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Huntsville, AL 35812
and
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SIGNIFICANT ACCOMPLISHMENTS FY81:

An automated technique for timely and accurate calculations of mesoscale winds using GOES satellite imagery has been developed and tested on a limited data sample. This technique calculates "feature" motion in sequences of images using template matching of image subscenes. Feature selection is done objectively to insure motions that are height assignable and are representative of the actual wind. Comparisons have been made between the "automated" winds and those 1) measured by the AVE IV special rawinsonde, 2) calculated by single pixel tracking at MSFC and 3) those calculated on the AOIPS/McIDAS systems. Results are encouraging to the point where future research and technique refinement have been proposed.

CURRENT FOCUS OF RESEARCH WORK:

Diagnostic evaluation of the automated mesoscale winds is currently underway on MSFC's MASS computer system. This work will determine the representativeness of these winds as compared to other surface and upper air measurements. In addition, reconfiguration of the computer code has allowed quasi-interactive processing so that these mesoscale winds estimates can be assimilated with other special data taken during AVE/SESAME periods.

PLANS FOR FY82:

We proposed the following new research: 1) technique refinement and improvement using VISSR data, 2) meteorological evaluation with AVE/SESAME/VAS special ground-truth measurements, 3) real-time testing on the McIDAS computer network and 4) improvements related to the use of VAS data.

RECOMMENDATIONS FOR NEW RESEARCH:

We recommend this method be implemented and tested in an operational environment to assess the usefulness of these wind estimates for numerical and short-range local severe weather forecasts possibly using the McIDAS computer network.

APPLICATION OF THE AVE-SESAME DATA SETS TO MESOSCALE STUDIES

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Contributors: Brian Auvine, H. Michael Goodman, Raymond Lord, David Santek, Arthur Thomas

Scope of Research:

To investigate the quantitative application of GOES data, complemented by conventional data, in the investigation of the structure and dynamics of severe local storms and convective outbreaks:

(1) Using the '79 SESAME-AVE storm-scale rawinsonde and radar data, improve the methods whereby rapid-scan satellite imagery can be combined with conventional meteorological observations to produce more useful data sets--this includes improved mesoscale wind fields for at least three levels, and combined satellite and digital radar maps of convection and small-scale thunderstorm features.

(2) Improve means whereby satellite brightness data can be used both to isolate deep convection and to detect severe weather in its incipient stages, and

(3) Complete more cases of investigating small-scale thunderstorm characteristics, and combine digital satellite and radar data to relate the occurrence of cold domes and overshooting tops to severe weather at the surface.

Accomplishments FY-81:

(1) Cloud Winds: Wind sets (from cloud tracers and raobs) for three levels, using 6 min sequences centered on 2115 and 2315 GMT for 2 May '79 are complete along with derived quantities such as divergence, vorticity and fluxes.

(2) Penetrating Tops: For 2 May '79, visible signatures, vis, IR and radar brightness fields and surface severe weather have been plotted at 6 min intervals and intercompared along with cloud and radar cross-sections.

(3) Anvil Statistics: For 2 and 20 May '79, relative areal growth rates for various brightness thresholds are compared with statistics of surface severe weather occurrences.

(4) Comparison of Satellite and Radar Brightness Statistics: For 20 May '79, we have begun investigating the relationship between radar, infrared and normalized vis satellite brightness data.

(5) Data Processing: Combining satellite, raob and aircraft winds; putting RHI, CAPPI radar remaps into satellite projections.

Current Focus of Research Work:

(1) Complete 1915 GMT wind set and analyses for 2 May, and begin wind sets for 20 May.

(2) Extend analyses of penetrating tops in time; begin work on 20 May and compare results.

(3) Relate shapes of anvil growth curves for various brightness levels to radar growth rates and types of severe weather occurrences.
(4) Continue direct statistical comparison between radar and satellite brightness; begin regression analysis and try to use satellite data to predict location of echoes/severe weather in areas lacking radar.
(5) Begin synthesis of above items to relate dynamics to satellite and radar severe weather statistics.

Plans for FY-82:

(1) Proceed as previously described to complete three case studies: an extremely active case (2 May), a moderately active case (20 May), and one with little activity (8 June).
(2) Work on relating the small scale dynamics to the anvil morphology and to the occurrence of severe weather at the surface.
(3) Continue to gather statistics on the relationship of satellite brightness to radar reflectivity and to location and type of severe weather. Apply these relationships to areas of no radar coverage.
(4) Interrelate our results (#2 & #3) for the three case studies to see how situation dependent they are.
(5) Incorporate VAS data into our studies.

Recommendations for New Research:

(1) Incorporate satellite signature information into forecasting routines.
(2) Test out satellite-radar relationships on more and varied cases.

Title: Diagnostic Analyses of the Environment of Severe Storms Using Atmospheric Variability Experiment (AVE) and Satellite Data.

Principal Investigator: Dr. James R. Scoggins
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Significant Accomplishments FY-81: Rawinsonde Sounding Data for both AVE VII and AVE-SESAME I were gridded vertical motion computed using the kinematic method with the O'Brien correction, and the moisture budget evaluated for three layers below 500 mb. Considerable effort was expended on the computation of vertical motion, and an attempt was made without success to modify the O'Brien correction scheme to make it more realistic. Also, considerable effort was expended on the evaluation and interpretation of the local time derivative and residual terms in the moisture budget equation. A 6-hr centered time difference was determined to be inadequate for computing the local time derivative. To circumvent their problem, the moisture budget equation was intergrated over time which makes it possible to express the equation in a more suitable form for analysis and interpretation. This form of the equation is now being evaluated.

The vorticity budget has been programmed but computations will not be performed until the moisture budget has been analyzed and interpreted. The reason is that results from the moisture budget analysis will aid in the vorticity budget analysis. This analysis will include the same three layers as the moisture budget analysis and will be for the same times.

Current Focus of Research Work: Our current focus is on the interaction between convective cloud systems and their environment. We hope to establish the energy source for convective activity, how the moisture is redistributed in the vicinity of the convective activity, and what influence the convective activity has on its near environment.

Plans for FY-82: Complete the analysis discribed above and properly document.

Recommendations for New Research: Mesoscale processes preceding, accompanying, and following the sessation of convective activity is inadequately understood. These mesoscale systems may be the key to accurate short range forecasts of thunderstorms, precipitation, and other short-period phenomena as well as influence significantly the larger scale systems. All available data and especially the VAS sounding data should be analyzed and interpreted with the objective of better understanding mesoscale systems, their utility in short range forecasting, and their influence on larger scale systems.

List of Publications Prepared since June 1980: The following reports were published in 1980 although the research was done prior to that time on another contract. No publications were prepared on the research described above.

List of Publications Prepared since June 1980: cont.

1. Davis, J. G., and J. R. Scoggins, 1981: The Development of Convective Instability, Wind Shear, and Vertical Motion in Relation to Convective Activity and Synoptic Systems in AVE IV. NASA CR-3386. pp. 131.

2. Scoggins, J. R., W. E. Carle, Keith Knight, Vance Moyer, and N. M. Cheng, 1981: A Comparative Analysis of Rawinsonde and Nimbus 6 and Tiros N Satellite Profile Data. NASA RP-1070. pp. 71.

3. Knight, K. S., and J. R. Scoggins, 1981: Atmospheric Structure Determined from Satellite Data. NASA RP-1071. pp. 95.

4. Carle, W. E., and J. R. Scoggins, 1981: Determination of Wind from Nimbus 6 Satellite Sounding Data. NASA RP-1072. pp. 72.

5. Cheng, N. M., and J. R. Scoggins, 1981: Comparisons Between Nimbus 6 Satellite and Rawinsonde Soundings for Several Geographical Areas. NASA RP-1073. pp. 64.

Title: AVE-SESAME Data Processing

Principal Investigator: Dr. James R. Scoggins
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Significant Accomplishments FY-81: The processing of rawinsonde soundings was concluded for six AVE-SESAME days. A preliminary look report was prepared for each day and data were placed on magnetic tape and a data report prepared.

Current Focus of Research Work: Concluded.

Plans for FY-82: None.

Recommendations for New Research: None.

List of Publications Prepared since June 1980: The reports published for 1980 are presented below for quick reference.

1. Williams, S. F., Nicholas Horvath, and R. E. Turner, 1980: A Preliminary Look at AVE-SESAME II Conducted on April 19-20, 1979. NASA TM-78280. pp. 49.

2. Williams, S. F., M. L. Gerhard, and R. E. Turner, 1980: AVE-SESAME II: 25-mb Sounding Data. NASA TM-78281. pp. 373.

3. Williams, S. F., Nicholas Horvath, and R, E, Turner, 1980: A Preliminary Look at AVE-SESAME III Conducted on April 25-26, 1979. NASA TM-78282. pp. 43.

4. Williams, S. F., M. L. Gerhard, L. P. Gilchrist, and R. E. Turner, 1980: AVE-SESAME III: 25-mb Sounding Data. NASA TM-78283. pp. 380.

5. July, M. J., and R. E. Turner, 1980: A Preliminary Look at AVE-SESAME IV Conducted on 9-10 May 1979. NASA TM-78314. pp. 51.

6. Sienkiewicz, M. E., L. P. Gilchrist, and R. E. Turner, 1980: AVE-SESAME IV: 25-mb Sounding Data. NASA TM-78315. pp. 386.

7. July, M. J., and R. E. Turner, 1981: A Preliminary Look at AVE-SESAME V Conducted on 20-21 May 1979. In Press.

8. Sienkiewicz, M. E., L. P. Gilchrist, and R. E. Turner, 1981: AVE-SESAME V: 25-mb Sounding Data. In Press.

9. July, M. J., and R. E. Turner, 1981: A Preliminary Look at AVE-SESAME VI Conducted 7-8 June 1979. NASA TM-82398. pp. 50.

10. Sienkiewicz, M. E., L. P. Gilchrist, and R. E. Turner, 1981: AVE-SESAME VI: 25-Sounding Data. NASA TM-82397. pp. 301.

Title: Storm Environment Interactions Determined from AVE-SESAME and Satellite Data

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Significant Accomplishments FY-81

Our goal is to better understand atmospheric conditions, especially features at the subsynoptic scale, that produce severe local storms and how these storms, once formed, alter their surroundings.

The subsynoptic-scale kinetic energy study of AVE-SESAME I (Red River Valley outbreak) was completed during FY-81. These results, utilizing rawinsonde data from both the routine NWS and special site locations, were compared with those obtained earlier using only the NWS sites. The energy balance was found to undergo major time variability that could not be detected using ordinary 12 h data. Interestingly, however, space patterns of the various parameters and many area-averaged numerical values are rather similar for the two sets of data. Special attention was placed on the formation of a strong upper-level wind maximum over Oklahoma that formed coincident with the tornado outbreak. Much of the time and space variability seen in the energetics is consistent with that hypothesized to be caused by feedback from intense convection.

Relative contributions of the divergent and nondivergent wind components to kinetic energy content, generation, and transport are being studied for the AVE IV period (April 1975). In the vicinities of two major convective areas, the divergent wind accounts for as much as 10% of the total kinetic energy content. Even more important, it produces up to 70% of the total cross-contour generation and 87% of the horizontal flux divergence of kinetic energy. Variations in the divergent component are as great as those of the nondivergent component. The results suggest that areas of severe storms greatly modify their surrounding wind fields through the divergent wind component. This is quite significant because current NWP forecast models inadequately treat the divergent component.

Adiabatic vertical motions were examined during the AVE-SESAME I case and compared with the more common kinematic vertical motions. At 500 mb, the kinematic motions clearly are superior; however, at 700 mb adiabatic velocities are nearly as good as the kinematic. Since synoptic-scale adiabatic vertical motions generally have been found to be inferior to the kinematic variety, we hypothesize that the 16 special RAOB sites and the special 3 h observation interval during AVE-SESAME I produce these improvements over past performance. The results suggest that it may be possible to compute meaningful adiabatic vertical motions from VAS sounder data.

Error analyses were conducted on all kinematic and kinetic energy parameters being studied. Such analyses are necessary to establish the effects of rawinsonde data errors on derived quantities. Besides establishing confidence limits in our results, such studies will serve as the standard by which satellite derived parameters are compared.

Structure functions have been computed on all basic parameters during the AVE-SESAME I period. These analyses show the relative activity of the various wavelengths. Wind parameters exhibit the greatest variability. Before severe storm development, synoptic-scale wavelengths are most active, but as the storms develop, wavelengths near 1100 km and 1600 km become dominant. The activity at these meso α-scales appears directly proportional to the intensity and areal coverage of storms within the area.

Current Focus of Research

During FY-81 we emphasized those storm-environment interactions detectable with data at 250-400 km spacings. During FY-82 we will focus on those interactions that are resolvable using data with spacings near 100 km (storm scale). TIROS and VAS sounder data are available at these resolutions, and we will make extensive use of these data sources during our investigations. With a more complete understanding of the smaller scales, we will be better able to utilize satellite data sources in forecasting routines and incorporate the effects of the smaller scales into numerical prediction models. Details of our plans are given in the next section.

Plans for FY-82

One of the three storm-scale AVE-SESAME cases will be selected for detailed analysis. Kinematic and kinetic energy parameters then will be evaluated over both the Oklahoma mesonetwork and the surrounding synoptic-scale area. A major task will be to incorporate computational procedures in the meso β-scale analysis that will lessen problems due to operating near the error range of the input data. Interactions between storms and their meso β-scale environments will be described.

A major new effort will begin to yield improved low-level, satellite-derived winds. This effort is desirable because previous studies based on RAOB data have shown that low-level kinematic parameters are strongly correlated with severe storm development. Our plan is to modify TIROS N - derived geostrophic winds such that they conform to well known boundary layer assumptions. We tentatively plan to use data from the AVE-SESAME I period. The low-level winds and parameters obtained therefrom then will be thoroughly evaluated against those from RAOB data and related with the locations of storms and other weather phenomena.

Recommendations for New Research

Based on our experience in deriving winds from TIROS N data, we wish to explore the merits of VAS data in defining the rapidly changing wind patterns prior to, and in the early stages of, severe storm development. Instead of using cloud-derived winds, we propose to obtain thermally-derived values. In the region below 850 mb, the total wind (not geostrophic) will be derived from boundary-layer equations such that the flow would conform to analyzed temperature fields obtained from the VAS. In the upper levels, standard thermal type wind equations will be used to derive the flow patterns. Thermally derived winds have been successfully obtained from TIROS data and are especially useful when trackable clouds are not located at the necessary horizontal and/or vertical locations of interest. Our proposed study would evaluate the usefulness of this technique on a smaller scale. Special emphasis will be placed on the short term variability of winds that the VAS provides. The thermally-derived wind patterns will be compared with RAWIN-derived values from

a concurrent special mesoscale network. Various kinematic (vorticity, wind shear, adiabatic vertical motion, moisture transport, etc.) and kinetic energy parameters will be computed from the winds to assess the impact of the VAS data in describing the atmosphere. These derived parameters also will be evaluated against RAOB-derived parameters. Our goal is to describe the advantages and limitations of a mesoscale thermal wind approach toward the diagnosis and eventual prediction of the severe storm environment.

Publications since June 1980:

Fuelberg, H. E., E. M. Berecek, D. M. Ebel, and G. J. Jedlovec, 1980: Kinetic energy budgets in areas of intense convection. NASA CR 3336, 184 pp.

Moore, J. T., and H. E. Fuelberg, 1981: A synoptic analysis of the first AVE-SESAME '79 period. Bull. Amer. Meteor. Soc., in press.

Jedlovec, G. J., and H. E. Fuelberg, 1981: A subsynoptic-scale kinetic energy study of the Red River Valley tornado outbreak (AVE-SESAME I). NASA CR, in press.

Fuelberg, H. E., and G. J. Jedlovec, 1980: Preliminary results of a kinetic energy study for the AVE-SESAME I period. Presented at the Extratropical Cyclone Workshop at Pennsylvania State University, July 1980.

Belt, C. L., and H. E. Fuelberg, 1981: The effects of random errors in rawinsonde data on derived kinematic quantities. Submitted to Mon. Wea. Rev.

Moore, J. T., and H. E. Fuelberg, 1981: A subsynoptic-scale analysis of the 10-11 April SESAME '79. Abstracts of SESAME 1979 Preliminary Results Workshop, Huntsville, AL, 17-19.

Jedlovec, G. J. and H. E. Fuelberg, 1981: A subsynoptic-scale kinetic energy analysis of the 10-11 April SESAME '79 period. Abstracts of SESAME 1979 Preliminary Results Workshop, Huntsville, AL, 21-23.

TITLE: MESOSCALE CIRCULATIONS AND CONVECTIVE STORM FORMATION

RESEARCH INVESTIGATOR: Gregory S. Wilson/ES84
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SIGNIFICANT ACCOMPLISHMENTS FY81:

NASA's unique AVE/SESAME I data were extensively analyzed to identify mesoscale structural features and dynamical processes influencing severe thunderstorm development during April 10-11, 1979. The primary purpose of this research was to establish the relative importance of mesoscale systems in creating environmental conditions favorable for thunderstorm and severe weather development.

Preliminary results have identified three strong meso-β scale systems, that were instrumental in creating environmental conditions favorable for strong thunderstorm development over the AVE/SESAME network. Two of these systems were associated with the development and movement of two separate convective storm complexes including the storm system containing the Wichita Falls, Texas tornado. TIROS-N satellite sounding data and GOES satellite imagery were used extensively to support these conclusions.

The strong controlling influence exerted by these systems over severe thunderstorm development points to the need to better understand and predict these features for improving severe storm and local weather predictions. The potential for improving severe weather understanding and prediction, using data from the new VAS was examined.

CURRENT FOCUS OF RESEARCH WORK:

GOES-W and special surface data are being analyzed to determine the initiating forces responsible for creating these meso-β scale systems. Analytical description of these wave-system characteristics is also being examined. Other TIROS-N sounding data are being used over the Western U.S. to assist in this analysis.

PLANS FOR FY82:

A three- dimensional trajectory model and satellite derived winds will be used to improve this diagnostic study relative to studying the dynamical characteristics of these meso-β systems.

RECOMMENDATIONS FOR NEW RESEARCH:

The use of the VAS instrument in this type of study is highly desirable. The execution of AVE/VAS will provide the satellite and ground-truth data to validate the VAS instrument performance and provide new mesoscale data to diagnostically and numerically study these types of mesoscale circulations. Improved understanding and prediction of severe storms depends on this type of measurement/research program.

TITLE: CHARACTERISTICS OF AGEOSTROPHIC MOTION IN THE VICINITY OF SEVERE WEATHER

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SIGNIFICANT ACCOMPLISHMENTS FY81:

The AVE-SESAME I storm case has been used to evaluate the ageostrophic motion present in the vicinity of a severe storm. The temporal and spatial ageostrophic characteristics have been determined using objective analysis techniques to analyze the height and observed wind fields derived from rawinsonde data. The geostrophic wind determined from the geopotential height fields are used along with the analysis of the observed winds to determine the vector ageostrophic wind. Results indicate that the region in which the storms develop are areas of maximum ageostrophic flow. The maximum ageostrophic flow (percentage of departure from the geostrophic wind) takes place at the time of most intense convective development and tornadic activity. Prior to the time of storm development, the maximum percentage departure from geostrophic speeds took place in the mid-troposhere, with the maximum departure approximately 55% less than the geostrophic wind at the 500 mb level at the time of first tornado information.

The horizontal components of the ageostrophic wind equation have been evaluated over the south central U.S. as well as within a small area bounding the storm active region. On the larger scale, results indicate that the ratio

$$(\hat{dV}/dt) \; / \; (\hat{dV}_g/dt)$$

ranges from a regional average of 3.5 at 800 mb to 2.5 at 200 mb. Decomposition of both total derivatives into local derivatives and advective terms indicate that all terms are of approximately the same magnitude. Contributions from local change terms tend to be slightly higher than advective terms near the surface but the ratio approaches unity in the upper troposphere.

CURRENT FOCUS:

Present emphasis is on the development of a four dimensional representation of the ageostrophic motion about a storm region. Two dimensional cross sections (Z,t) for the relative magnitudes of component terms in the ageostrophic wind equation are being constructed and identifiable aspects of the ageostrophic flow are being related to storm development. Surface features and weather are being integrated into the overall picture of storm development in order to relate that to the ageostrophic behavior in the area of storm activity.

PLANS FOR FY 82:

A continuation of FY 81 efforts will be carried out in 82. Additional AVE-SESAME cases will be incorporated into the study in order to generalize the results.

Characteristic ageostrophic motion-severe weather related relationships will be defined. Emphasis will also be placed on using such relationships to enable the identification of potential severe weather regions from space using cloud motion and thermodynamic parameters derived from geostationary platforms.

RECOMMENDATIONS FOR NEW RESEARCH:

Height fields derived from VAS soundings along with cloud motion vectors should be used to evaluate the ageostrophic motions present in the atmosphere based on satellite observations. An AVE-VAS type program should be carried out to support this goal in order to evaluate the mesoscale structure in both space and time.

PUBLICATIONS:

Abstracts of Proceedings at the SESAME 1979 Preliminary Results Workshop, Huntsville, Alabama, March 24-25, 1979.

Diagnostics of Severe Convection and Subsynoptic Scale Ageostrophic Circulations

Donald R. Johnson, Space Science & Engineering Center,
The University of Wisconsin-Madison

Significant Accomplishments FY-81:

The principle research thrusts during FY81 continued to be diagnostic and numerical studies of ageostrophic motion attending jet streak circulations and the development of deep convection. The diagnostic studies have focused on the AVE-IV severe weather events and have culminated in a physical perspective of the link between mass circulations imbedded within the MCCs and the direct branch of jet streaks along with a comparison of the semi-geostrophic forms for ageostrophic motion. The numerical and theoretical work includes: 1) model development to include heating and viscous processes for the study of their effects on jet streak circulations, 2) development and study of a model of ageostrophic motion divided into pseudo-geostrophic and pseudo-ageostrophic components that contain explicit degrees of freedom for the effects of diabatic heating and friction, 3) the comparison of the model's mass-momentum evolution from initialization based upon geostrophic and pseudo-geostrophic velocities and 4) the study of the depth of the planetary boundary layer as a function of the vertical variation of absolute vorticity through pseudo-geostrophic concepts. The development work for the hybrid isentropic-sigma coordinate model has also included the improvement of flux calculations for truncated isentropic grid volume adjacent to the interface between the isentropic and sigma domains and an enhancement of horizontal resolution.

In the initialization experiments, utilizing pseudo-geostrophic concepts of steady isentropic flow, inertial components of ageostrophic motion are determined through the distributions of absolute vorticity and kinetic energy superimposed on the geostrophic state. Variations of vorticity lead to inertial components of ageostrophic motion along the geostrophic flow while the gradient of kinetic energy associated with finite length jets leads to components of ageostrophic motion normal to the geostrophic current. Comparison of model integration with geostrophic and pseudo-geostrophic initial conditions have revealed the following: 1) the ageostrophic motion implicit in pseudo-geostrophic initial conditions contain realistic direct and indirect mass circulations, 2) with geostrophic initial conditions, realistic direct and indirect mass circulations only develop after six to nine hours of integration that are accompanied by spurious gravity inertial oscillations, 3) the evolution of the velocity structure and fields of divergence of propagating jets from the pseudo-geostrophic experiments are well behaved, 4) the structure of the ageostrophic motion evolving from the pseudo-geostrophic and geostrophic initial conditions differed substantially during 36 hours of the experiment. Adiabatic inviscid experiments have also been conducted to study the undesirable growth of the computational mode which has been reduced by changing the time step from 5 to 2.5 minutes.

The model development to include viscous processes is based on the flux methodology. The net frictional force is determined by boundary stresses on the grid volume element (including truncated volume elements) thereby readily satisfying integral constraints for momentum diffusion. At the same time,

improved methods of interpolation for physical processes within truncated volumes near the interface have been included. The modifications more accurately partition the vertical exchange of mass and momentum across the interface in the presence of diabatic and viscous processes and reduce artificial jumps in mass-momentum structure as isentropic grid points emerge and submerge through the interface. In order to run on the Marshall Univac 1110 computer and increase the horizontal resolution, the effort to allow doubling and quadrupling the horizontal resolution of 275 km has required extensive reprogramming of the model. The integration for each time step proceeds through computations by successive vertical-meridional slabs instead of by successive horizontal layers.

In conjunction with the development of the planetary boundary layer of the hybrid isentropic-sigma coordinate model, a generalization of the Ekman solution is used to study the role of vertical variation of the absolute vorticity on the depth of the planetary boundary layer. The preliminary results indicate that the planetary boundary layer depth is greater than the Ekman depth for a linear variation of vorticity with height where relative vorticity being zero at the earth's surface decreases to the range of values, $(-0.6f_0<f<f_0)$, at the top of the Ekman layer. Outside this range of values, the depth of the boundary layer is less than the Ekman solution. The results suggest that anticyclonic motion in the low troposphere near and ahead of the approaching squall line leads to a deeper planetary boundary layer and helps to explain how planetary boundary layer convergence becomes coupled with deep convection.

Twice during the AVE-IV experiment, the winds in the two jet cores increased by some 10-20 m/s over a period of 6-12 hours as the jet cores moved across the AVE-IV region. Associated with these events were intense mesoscale convective complexes which developed in the right rear flank of the jet cores prior to acceleration in both cases; results noted previously by several investigators.

The total ageostrophic wind expressed in isentropic coordinates for frictionless motion is:

$$\underset{\sim}{U}_{ag} = f^{-1}\,\underset{\sim}{k} \times \left[\frac{\partial \underset{\sim}{U}}{\partial t_\theta} + \underset{\sim}{U}\cdot\nabla_\theta \underset{\sim}{U} + \frac{d\theta}{dt}\frac{\partial \underset{\sim}{U}}{\partial \theta}\right] .$$

A B C

The results from the large scale study have shown that the inertial advective component, term B, dominates at jet level (330K) when little convective activity is present. Upon MCC development, however, the vertical inertial term, C, and the isallobaric component of A become important components of ageostrophic motion. The results show that the mass circulation of the MCC located in the right rear flank of the jet streak is in the same sense as the direct circulation of the jet streak. The net isallobaric motion that is linked with differential heating exceeds 8 m/s at the jet stream level while the inertial diabatic component associated with C ranges from 5-10 m/s both of which are directed in the convective portion of the entrance region towards lower pressure. Through the diabatically forced ageostrophic motion, the mass circulation in the MCC region is intensified, kinetic energy is generated by flow towards lower pressure and the momentum of the jet core is increased.

As expected, a comparison between complete and semi-geostrophic forms for ageostrophic motion emphasizes that within the lifetime of the MCC the accuracy of semi-geostrophic concepts in describing the structure of atmospheric motion is limited. The differences between estimates of total and semi-geostrophic ageostrophic winds as large as 20 m/s were mainly linked to differences between inertial advective components of ageostrophic motion.

Current Focus of Research Work:

The current foci are the completion of development of the hybrid isentropic-sigma coordinate model to include viscous and diabatic processes, continuation of mass-momentum adjustment experiments of jet streaks and completion of the AVE-IV case study. In these efforts, the importance of the components of ageostrophic motion associated with various physical processes that force the development of severe storms are being compared.

Plans for FY-82:

The principle work during FY-82 will be to complete a series of numerical experiments for the study of subsynoptic scale ageostrophic circulations of propagating jet streaks and severe weather and the completion of model development. This series of experiments will be carried out to determine the effect of diabatic and viscous processes through examining the role of various modes (adiabatic, diabatic, viscous, transient) of ageostrophic motion in mass-momentum adjustment.

Recommendations for New Research:

The structure and evolution of ageostrophic motion associated with mesoscale mass-momentum adjustment, precipitation and severe weather events should be assessed through conventional and satellite observations and through numerical simulations in order to improve mesoscale prediction. The effort to assimilate VAS satellite and conventional data in mesoscale weather prediction is exceedingly difficult. Particular emphasis should be devoted to the analysis of the balance of the mass-momentum structure in initialization, ageostrophic motions and the distribution of water vapor associated with mesoscale precipitation events.

List of Publications Prepared since June 1980:

Johnson, D. R. and L. W. Uccellini, 1981: A comparison of methods for computing the sigma coordinate pressure gradient force for flow over sloped terrain. (manuscript)

Keyser, D. A., 1981: Effects of diabatic heating on the ageostrophic circulation of an upper tropospheric jet streak. (M.S. thesis)

TITLE: AVE-SESAME DATA PROCESSING

RESEARCH INVESTIGATORS: Dr. Robert E. Turner
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SIGNIFICANT ACCOMPLISHMENTS FY 81:

NASA's Marshall Space Flight Center (MSFC) participated in a large inter-agency mesoscale and severe storms experiment identified as AVE-SESAME '79 (Atmospheric Variability Experiment - Severe Environmental Storms and Mesoscale Experiment 1979). A primary objective of NASA is to acquire carefully edited sets of rawinsonde data during selected severe weather events for use in correlative and diagnostic studies with satellite and radar data obtained during the same periods.

AVE-SESAME '79 data acquired on April 10-11, 19-20, 25-26, and May 9-10, 20-21, and June 7-8, 1979, has been edited and processed. These data are from approximately 20 supplemental and 23 standard rawin sites.

CURRENT FOCUS OF RESEARCH WORK:

The major focus for the coming months will be to use these unique data sets for mesoscale research to determine the value of satellite sensors for detection of mesoscale systems. Tapes and hard copies for each of these cases are available upon request to Director, Space Sciences Laboratory, MSFC, Alabama 35812.

PLANS FOR FY 82:

Study of the AVE-SESAME cases in conjunction with satellite data for a better understanding of mesoscale weather phenomena and their interactions with larger scales.

RECOMMENDATIONS FOR FOLLOW-ON RESEARCH:

Research on the AVE-SESAME experiments data needs to be extended far beyond its present level. The present research is a good start but by no means comprehensive.

PUBLICATIONS:

AVE-SESAME II: 25-mb Sounding Data, NASA TM 78281, June 1980
A Preliminary Look at AVE-SESAME II Conducted 19-20 April 1979 NASA TM 78280, June 1980.

AVE-SESAME III: 25 mb Sounding Data, NASA TM 78283, June 1980.
A Preliminary Look at AVE-SESAME III Conducted 25-26 April 1979 NASA TM 78282, June 1980

AVE-SESAME IV: 25 mb Sounding Data, NASA TM 78315, November 1980.
A Preliminary Look at AVE-SESAME IV Conducted 9-10 May 1979, NASA TM 78314, November 1980

AVE-SESAME V: 25 mb Sounding Data, NASA TM 82417, May 1981
A Preliminary Look at AVE-SESAME V Conducted on 20-21 May 1979, NASA TM 82416, May 1981

AVE-SESAME VI: 25 mb Sounding Data, NASA TM 82397, January 1981.
A Preliminary Look at AVE-SESAME VI Conducted 7-8 June 1979, NASA TM 82398, January 1981.

NASA's AVE-SESAME '79 Rawinsonde Data, SESAME Data Users Workshop, Boulder, Colorado, January 1981.

Proceedings of the SESAME 1979 Preliminary Results Workshop, Huntsville, Alabama, March 1981

TITLE: AN APPLICATION OF VAS/TIROS SOUNDING INFORMATION TO DEFINE VERTICAL CIRCULATION IN POTENTIAL STORM AREAS

RESEARCH INVESTIGATOR: James E. Arnold
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SIGNIFICANT ACCOMPLISHMENTS FY81:

Examination of the constant pressure height fields in the AVE-SESAME I storm case revealed that a series of short waves propagated through the storm region during the period of maximum activity. These waves could be followed in the height change field determined from the radiosonde information as well as be identified in the constant pressure height fields determined from the TIROS N sounder. Since convective storms can be associated with the larger scale vertical motion field imposed by the short waves, a technique which would allow the identification of the short waves and the associated motion field from satellite measurements should be of some value in storm diagnostics and storm forecasting.

Height fields at constant pressure levels are currently developed from TIROS and VAS sounder information and are prime candidates for consideration in the assessment of a potential storm situation. In the case of VAS sensor, height fields can potentially be determined on an hourly or three hourly basis. From such height fields, short wave propagation can be followed and used to define severe weather situations.

Use of radiosonde data acquired during AVE-SESAME I indicates that the short wave systems could be followed in the height change field and that the waves associated with the height changes could also be correlated with the outbreaks of convective activity. A vertical motion field over the storm area was developed from the isallobaric component of the ageostrophic wind. This motion field agreed well with the vertical motion determined from the observed winds over the area. From comparisons made on a single case, it seems that the vertical motion field in a region can be defined from the height change field on a series of constant pressure charts. Similar vertical motion fields should be able to be developed using satellite derived height fields and the associated change fields.

CURRENT FOCUS:

Emphasis is currently being placed on relating upper level perturbations to surface phenomena and the life cycle of individual storm complexes. The TIROS-N soundings have been placed in an AVE-VAS format and an examination of the three dimensional structure of the developed geopotential height fields is being undertaken.

PLANS FOR FY 82:

A continuation of the study to relate short wave features to severe weather based on the AVE-SESAME data sets is planned. The ability of the TIROS-N type soundings to resolve short wave features will be carried out using additional AVE-SESAME data sets. The representativeness of the isallobaric component of the ageostrophic wind to determine a vertical motion field will be examined using other AVE-SESAME data sets.

RECOMMENDATIONS FOR NEW RESEARCH:

Time series of VAS derived height fields should be obtained coincident with an AVE-type rawinsonde program. Such a program would enable the verification of the ability of the VAS sounding technique and derived height fields to resolve mesoscale or short waves in a storm active region.

TITLE: A SATELLITE RADIANCE VARIABILITY EXPERIMENT

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SIGNIFICANT ACCOMPLISHMENTS FY81:

Retrieval of temperature/moisture profiles with TIROS/VAS Sounder techniques results in radiance/temperature values which are a vertical and horizontal weighted value, depending on the vertical weighting profile for individual channels and the response within the field of view for the detector. In reality, each assigned value of temperature is a vertical and horizontal integration of actual atmospheric conditions within the scan volume. Representativeness of the assigned temperature then becomes dependent upon the local atmospheric variability in the horizontal and vertical within the scan volume.

In order to evaluate the representativeness of assigned temperature values in the sounding retrieval techniques, a limited field program in which the volumetric variability within the scan volume of the sounder can be measured, has been developed. The goal is to measure the three dimensional temperature and moisture structure within the scan volume at the same time that satellite radiance measurements are being obtained. This "ground truth" will be used to compare radiance values and assigned temperatures with observed conditions. The measurement program will:

1) Evaluate the horizontal and vertical variability on the scale of the scan volume utilizing special network data.

2) Provide radiosonde measurements coincident with the time a sounding sample is obtained. Tentative plans are to have the sounding balloon at 500 mb at the time the sounding is obtained.

Radiance contributions for individual layers will be established based on radiosonde measurements and estimates of radiance variability based on temperature/moisture variability within the scan volume. These estimates will be compared with derived measurements made from TIROS and VAS sounders.

CURRENT FOCUS OF RESEARCH:

Current research efforts are centered on the testing of measurement techniques and retrieval techniques as applied to the comparison program. AVE-SESAME data is being used to provide preliminary evaluations of the temporal and spatial variability of atmospheric parameters on scales approaching those desired in the

radiance variability experiment.

PLANS FOR FY 82:

The SRVE will be implemented as part of the 1982 AVE/VAS Ground Truth Experiment. Additional evaluation will take place at the Marshall Space Flight Center with a denser RAOB network than in the AVE/VAS experiment. Initial analysis of the data will be implemented during this fiscal year.

RECOMMENDATIONS FOR NEW RESEARCH:

Four dimensional variability measurements on the scale of the sensor scan volume should be carried out and used as a basis for defining the measurement capability of such sensors at the meso α and meso β scales and for future sensor evaluation.

TITLE: 1982 GROUND TRUTH FIELD EXPERIMENT

RESEARCH INVESTIGATORS: Dr. Robert E. Turner
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SIGNIFICANT ACCOMPLISHMENTS FY 81:

NASA's Marshall Space Flight Center (MSFC) will participate in and manage a large mesoscale and severe storms experiment identified herein as the AVE/VAS Ground Truth Field Experiment. A special meso-α and meso-β network has been planned that will allow horizontal and vertical observations of temperature, moisture, and winds on a scale comparable with VAS. The network will operate for three 24-hour special observing periods taking soundings every three hours. The three observing periods are planned for March-May of 1982 and will include at least one period of relatively clear, calm weather and two periods of severe storm and other precipitation events.

The present Rawin System is being reworked to insure minimum problems in the Field Experiment.

CURRENT FOCUS OF RESEARCH WORK:

The major focus for the coming months will be to continue to keep abreast of GOES, D, and E, and F schedules. To continue refurbishing the Rawin Systems. To publish a description and operation plan.

PLANS FOR FY 82:

To manage and participate in the FY 82 experiment.

RECOMMENDATIONS FOR FOLLOW-ON RESEARCH:

Develop retrieval techniques which are optimized for local geostationary sounding applications. Determine the vertical and horizontal resolution of VAS soundings. Assimilate comprehensive meteorological and simulated radiance data for selected case studies so that they will be available for severe storms research. Determine the retrievability of meteorological parameters based upon the combination of VAS data, ancillary data, and physical principles. Determine the accuracy of the VAS temperature and moistuer profiles (derived from VAS and ancillary data) relative to both special networks and existing data sources. Determine the impact of VAS data upon analyses of severe weather situations through extensive diagnostic

meteorological analyses. Assessing and developing temperature and moisture sounding-retrieval techniques which maximize information content relevant to important atmospheric, thermodynamic, and dynamic processes. Developing assimilation techniques and objective analysis schemes which effectively combine data from various sources and minimize data redundancy while meeting basic dynamic constraints in nowcasting/ mesoscale forecasting systems.

PUBLICATIONS:

1981 AVE/VAS GROUND TRUTH FIELD EXPERIMENT DESCRIPTION AND OPERATIONS PLAN

VAS DEMONSTRATION: NASA/MSFC's PARTICIPATION IN VAS DEMONSTRATION LAUNCH READINESS REVIEW, GSFC, August 1980.

VAS SPECIAL MESOSCALE NETWORK, VAS WORKSHOP, GSFC, December 1980.

TITLE: COOPERATIVE CONVECTIVE PRECIPITATION EXPERIMENT (CCOPE)

RESEARCH INVESTIGATORS: Dr. Robert E. Turner
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SIGNIFICANT ACCOMPLISHMENTS FY 81:

NASA's Marshall Space Flight Center (MSFC) participated with its Rawin Systems in a large inter-agency mesoscale and storms experiment during the summer of 1981 in Montana (May 11-August 7). A primary objective of NASA is to support an effort to acquire mesoscale rawinsonde data during selected weather events to identify, describe and understand the most important aspects of many scale interaction events; hydrometer evolution, precipitation efficiency, origins of ice, entrainment, storm structure and the environment, storm initiation, atmospheric chemistry, and storm electrification.

CURRENT FOCUS OF RESEARCH WORK:

The major focus for the coming months will be to continue to keep abreast of CCOPE data processing and schedules. To identify scientific studies that can be conducted involving mesoscale as well as synoptic scale phenomena.

PLANS FOR FY 82:

Coordination with NCAR and WPRS and assistance when necessary, in the data processing and analysis.

RECOMMENDATIONS FOR FOLLOW-ON RESEARCH:

Use satellite cloud cover climatology to improve and provide a physical explanation for the observed severe storm climatology.

TITLE: COOPERATIVE CONVECTIVE PRECIPITATION EXPERIMENT (VAS/CCOPE)

RESEARCH INVESTIGATORS: Dr. Robert E. Turner
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SIGNIFICANT ACCOMPLISHMENTS FY 81:

NASA's Marshall Space Flight Center (MSFC) participated in a large inter-agency mesoscale and storm experiment during the summer of 1981 in Montana. A primary objective of NASA is to acquire VAS soundings on scheduled days during adverse weather events to identify, describe, evaluate and understand the comparison of the VAS soundings with ground based measurements.

CURRENT FOCUS OF RESEARCH WORK:

The major focus for the coming months will be to compare the VAS soundings data with correlative ground truth measurements.

PLANS FOR FY 82:

Coordinating with NCAR, WPRS, University of Wisconsin, NOAA and GSFC and assisting when necessary in the data processing and analysis.

RECOMMENDATIONS FOR FOLLOW-ON RESEARCH:

Assess the impact of VAS soundings at high latitude. Examine the possibility of operational use of data.

Title: The Impact of Diabatic Heating on the Evolution of Extratropical Cyclones.

Research Investigator Involved: Franklin R. Robertson
USRA
ES83/MSFC, AL 35812

Significant Accomplishments FY-81:

A diagnostic energetics analysis was used to study the effects of moisture-related heating on three numerically simulated cases of cyclone development. Both kinetic and available potential energy budgets were partitioned into zonal and eddy quantities in order to focus more effectively on cyclone-scale processes. Model forecasts used were from moist and dry versions of the Drexel University Limited Area Mesoscale Prediction System (LAMPS).

Analysis of the LAMPS forecasts showed that baroclinic processes were noticeably enhanced by both stable and convective latent heat release. Conversion of zonal available potential energy (AZ) to eddy available potential energy (AE) and release of AE with subsequent conversion to eddy kinetic energy(KE) were strengthened considerably. In addition, virtually all of the AE release due to moist processes was realized as KE. Resulting KE contents were consistently higher in the moist forecasts.

Modification of jet stream structures by diabatic heating was also studied. Increased generation of KE in the moist forecasts resulted in strengthening of upper level flow north(on the cold air side) of precipitation regions as well as increased low level (600-700 mb) flow on the warm side of precipitation regions. These responses to diabatic heating, which were absent in the dry forecasts, represent adjustment by the large-scale flow toward hydrostatic and geostrophic equilibrium.

Current Focus:

Present work is directed toward a review of diagnostic moisture parameterization schemes which would allow comparisons of model-derived energetics with verifying data.

Plans for FY-82:

The immediate objective is development of a diagnostic parameterization scheme which is general enough to treat ensemble convection as being responsive both to large-scale and mesoscale forcing. This effort will involve use of satellite-derived information on cloud field properties.

TITLE: MEDIUM-RANGE THUNDERSTORM FORECASTS FROM THE LIMITED AREA FINE MESH MODEL

RESEARCH INVESTIGATOR: Gregory S. Wilson/ES84
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SIGNIFICANT ACCOMPLISHMENTS FY81:

Operational testing at the National Severe Storms Forecast Center and objective verification of the thunderstorm forecasts from past storm seasons has improved the performance and interpretation of this forecast guidance product. Individual case-studies from the AVE/SESAME data base have also been analyzed in-depth to assess the performance of the LFM forecasts and thunderstorm predictions relative to detailed diagnostic calculations and verification data already available for these periods. This research has demonstrated that medium-range thunderstorm forecast guidance from this technique is a needed and valuable product.

CURRENT FOCUS OF RESEARCH WORK:

NSSFC would like to incorporate these forecast products into their McIDAS/CSIS computer network for easier display and interpretation. The computer code has been transferred from MSFC to the University of Wisconsin so that it can be executed on demand from the NSSFC and MSFC McIDAS terminals through a remote job entry to NMC's 360/195's. Final predictions would then be transferred to the individual McIDAS terminals for color graphics display, contouring, and animation.

PLANS FOR FY82:

Real-time execution of these predictions through the McIDAS network will be completed. Communications between NSSFC and MSFC via the McIDAS network will allow NASA scientists to work more closely with severe weather forecasters relative to this forecast guidance product. Changes will be incorporated in order to improve the product based upon objective verification and real-time testing at MSFC and NSSFC.

RECOMMENDATIONS FOR NEW RESEARCH:

Incorporation of this product as a regular part of the CSIS system is recommended. Also, improvements in the numerical model predictions either from better initialization using satellite data and/or from new mesoscale models will directly improve the performance of this longer-range thunderstorm forecast system.

TITLE: MESOSCALE AND SEVERE STORMS (MASS) COMPUTER SYSTEM DEVELOPMENT

RESEARCH INVESTIGATORS: John S. Hickey
ACI
Huntsville, Alabama 35801

SIGNIFICANT ACCOMPLISHMENTS FY81:

An interactive hardware/software computer system has been designed and partially implemented to allow atmospheric scientists to graphically display and analyze large volumns of conventional and satellite-derived meteorological data. Data-base-management software was developed and tested so that all AVE-type experiment data are disk-resident and easily available to the general-purpose plotting and analysis software.

CUURENT FOCUS OF RESEARCH WORK:

At present, the software configuration has been modified to allow general-purpose plotting and data-base-management of many case-study periods and various meteorological data types. Work is nearly complete on software to plot and analyze all types of "sounding" or "vertical profile data" (i.e., AVE or VAS or TIROS/NOAA soundings) and for comparing these data sets.

PLANS FOR FY82:

Software and hardware modifications will be implemented to:

1) increase the disk-resident data base to 150 mbytes.
2) provide for color graphics and imaging.
3) allow processing of 7 basic meteorological data types (i.e., surface, image, grid-point, etc.).

RECOMMENDATIONS FOR NEW RESEARCH:

A central processing unit (CPU) has become available for our system that would allow interactive image-processing and numerical weather research related to the use of satellite imagery and soundings. We recommend that this hardware be added to this current system to bring state-of-the-art research capability to the MSFC's Mesoscale and Severe Storms Program for those tasks requiring CPU-bound computer processing requirements.

TITLE: METEOROLOGICAL APPLICATIONS OF SPACE PLATFORMS

RESEARCH INVESTIGATORS: Gregory S. Wilson/ES84
William W. Vaughan/ES81
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SIGNIFICANT ACCOMPLISHMENTS FY81:

Earth-viewing instrumentation, determined as possible payloads for the Science and Application Space Platform by OSTA, has been researched to assess those payload accommodations/instrument characteristics that would be design drivers for the final SASP design. This information has been used to establish two basic SASP design concepts from which the final SASP configuration will be chosen.

CURRENT FOCUS OF RESEARCH WORK:

Examining the space platform concept to assess its applicability to meteorological payload opportunities in both operational and research environments.

PLANS FOR FY82:

Existing and new meteorological payloads with both research and operational applications will be assessed from a platform standpoint.

RECOMMENDATIONS FOR NEW RESEARCH:

Establish preliminary design studies of instrument complements for meteorological applications based upon space platform capabilities and scientific needs. Focusing on precipitation measurements from space, from either passive or active sensors, would provide a start toward remotely measuring this important mesoscale process.

TITLE: APPLICATION OF THE MSFC DOPPLER LIDAR TO RESEARCH ON MESOSCALE ATMOSPHERIC PHENOMENA

RESEARCH INVESTIGATOR: G. D. Emmitt
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SIGNIFICANT ACCOMPLISHMENTS FY81:

At the University of Virginia, AVE/SESAME data have been used to study the nocturnal jet and storm boundary layer outflows. Since joining the MSFC in July '81, I have participated in the airborne measurement program for the Doppler Lidar (CCOPE-Montana), proposed several ground-based studies that would aid in the interpretation of the data acquired during those tests, and begun the process of choosing a mesoscale model(s) that can serve our in-house research needs.

CURRENT FOCUS OF RESEARCH:

Research on severe storms, in particular their initiation, requires measurements at times when there are no clouds to be sensed by satellite or radar. The Doppler Lidar may be the instrument that can resolve the meso-γ mass convergence fields that precede severe storm development. Current research is directed towards developing the Lidar into a viable mesoscale wind measuring system.

PLANS FOR FY82:

There are two major objectives for FY82:

1) Assay the capabilities, both current and projected, of the airborne Doppler Lidar as a viable mesoscale research tool. This would include the performance of several ground-based studies and analysis of data collected during the recent airborne tests.

2) Acquire a mesoscale model that will serve in a feasibility study of the use of remote sensors (satellite, airborne and ground-based) to describe the cloud-free pre-storm environment.

TITLE: Backscatter Research for Remote Measurement of Winds from Space

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SIGNIFICANT FY-81 ACCOMPLISHMENTS:

A number of important objectives were met during FY-81.

a. An aerosol committee was formed, headed by Dr. Theodore J. Pepin of the University of Wyoming. The role of the aerosol committee was to assess the existing data on atmospheric scattering at 10.6 μm. The consensus of the committee was that few measurements had been made at this wavelength; that it was inappropriate to extrapolate to this wavelength from measurements made in the visible portion of the spectrum; and that in fact, one could not safely infer levels of backscatter at 9.1 μm (one of the possible wavelengths mentioned for use in the proposed WINDSAT system) from data collected at 10.6 μm.

b. An instrument to measure backscatter at the single wavelength of 10.6 μm was designed and assembled under OAST sponsorship. The initial calibration of the instrument for volume mode operation was accomplished, and techniques for characterizing the response to single aerosols were identified and necessary preparations were started to utilize these techniques. Operation of the instrument aboard the NASA/Ames CV-990 aircraft was demonstrated during July 1981 (SSP flights 10-21). Numerous backscatter profiles were obtained at several locations in the Continental U. S.

c. In response to the final report from the aerosol committee, a RFQ for the conceptual design of a 3-wavelength backscatter measurement system was released. The data from the 3-wavelength system will complement the data from the DLS instrument and FSSP instrument. Finally, preparations are underway to participate in the autumn JPL radar missions.

FY-82 PLANS:

During FY-82, the conceptual design of a 3-wavelength system will be completed and work begun on the instrument. In addition, data will be collected by the DLS in its ground-based configuration. The data will consist of vertical soundings made at the beginning and end of each operational day.

RECOMMENDATIONS FOR NEW RESEARCH:

A search should be undertaken to identify alternate means of collecting data which could be used to determine backscatter profiles. These methods and the data provided would constitute a valuable cross-check on the data collected by the backscatter instrument and the DLS. If the techniques require only ground-based, simple apparatus then many measurements could be made, thus establishing the required data base much more rapidly.

PUBLICATIONS:

"Design and Calibration of a Coherent Lidar for Measurement of Atmospheric Backscatter"
W. Jones, J. Bilbro, S. Johnson - MSFC
C. DiMarzio - Raytheon Company
R. Lee - Lassen Research
L. Kennedy, H. Jeffries - Applied Research, Inc.

"A Plan for the Determination of Atmospheric Effects on a Satellite-Borne Doppler Lidar for Global Wind Measurements"
(FY-81 efforts)
J. Bilbro, W. Jones, R. Smith - MSFC

Recommendations for New Research

A search should be undertaken to identify alternate means of collecting data which could be used to determine backscatter profiles. These methods and the data provided would constitute an valuable cross-check on the data collected by the backscatter instrument and the DLS. If the techniques required only ground-based, simple apparatus, then many more measurements could be made, thus establishing the required data base much more rapidly.

Publications: "Design & Calibration of a Coherent Lidar for Measurement of Atmospheric Backscatter".
W. Jones, J. Bilbro, S. Johnson, MSFC
C. DiMarzio, Raytheon Co.
R. Lee, Lassen Research
L. Kennedy, H. Jeffries, Applied Research, Inc.

"A Plan For The Determination of Atmospheric Effects on a Satellite-Borne Doppler Lidar For Global Wind Measurements," (FY '81 Efforts).
J. Bilbro, W. Jones, and R. Smith.

TITLE: AN EFFICIENT BETA MEASUREMENT STRATEGY

RESEARCH INVESTIGATOR: David A. Bowdle
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(205) 453-5218 or FTS 872-5218

SIGNIFICANT ACCOMPLISHMENTS FY 81:

An efficient airborne sampling strategy has been developed for the determination of the global distribution of the aerosol back-scatter cross-section (Beta) at infrared wavelengths near 10.6 μm in the mid and lower terrestrial atmosphere. The advantage of this proposed sampling strategy is its optimization of expensive aircraft flight time.

The proposed strategy is based on the assumption that the atmosphere may be considered to be composed of a few discrete boxes, each of which occupies a particular volume of the atmosphere and is characterized by a particular mean value and standard deviation for Beta. The boxes are primarily phenomenological in nature, rather than spatial, temporal, or geographical.

Aircraft deployment is arranged so as to ensure a high probability of encountering the desired phenomenological box. In this case, the box of interest is the upper tropospheric box, which is characterized by the lowest mean value of Beta. Enough measurements are obtained in this box to verify that it is a single box and not a composite, as well as to determine the mean and standard deviation of Beta and the volume of the box to the desired level of confidence.

The results of a global Beta measurement program based on this type of sampling strategy are expected to be sufficient to define the power level required for the effective measurement of global winds using a satellite-based infrared laser doppler system.

CURRENT FOCUS OF RESEARCH WORK:

Natural atmospheric tracers are being sought which are easily measurable and also are characteristic of one or more of the phenomenological atmospheric boxes. Tracer measurements would be expected to increase the confidence level in the measured minimum mean value of Beta, to decrease the scatter in the Beta measurements, and also to reduce the magnitude of the measurement program.

PLANS FOR FY 82:

Airborne measurements of Beta and of related aerosol parameters will be obtained this fall and on later flights as available. The results of these measurements should suffice to test the "Box Hypothesis" and to define the scope of the subsequent global Beta measurement program.

RECOMMENDATIONS FOR NEW RESEARCH:

Global measurements of Beta, with companion measurements of aerosol parameters and atmospheric tracers, should be performed using the strategy outlined above. Such a measurement program would not only provide the basis for engineering and management decisions on the proposed satellite-based wind measurement system, but it would also provide valuable information to the scientific comunity on selected parameters of the global background aerosol.

TITLE: STRATOSPHERIC/TROPOSPHERIC AEROSOL MEASUREMENTS PROGRAM (STAMP)

RESEARCH INVESTIGATOR: David A. Bowdle
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SIGNIFICANT ACCOMPLISHMENTS FY 81:

Airborne measurements of atmospheric aerosol particles were obtained over the western continental United States from June 12 - July 31, 1981. Flight altitudes covered the range from near the surface up to the lower stratosphere. A variety of meteorological conditions were encountered including the convective boundary layer, the clear air environment of large convective clouds, and the undisturbed middle atmosphere.

The aerosol measurements were obtained with an optical particle counter (PMS FSSP-100, or Particle Measuring Systems Forward Scattering Spectrometer Probe) on loan from NASA-Langley Research Center. This device is capable of measuring in-situ the size and concentration of aerosol particles between 0.5 and 45 μm diameter. The FSSP was mounted on the wingtip of a Convair 990 jet aircraft based at Ames Research Center. The aerosol measurements were obtained in conjunction with the MSFC Doppler Lidar System Severe Storms Field Program.

CURRENT FOCUS OF RESEARCH WORK:

The data which were obtained during the summer flight program are being reduced and analyzed. Data validation will include a manufacturers calibration of the FSSP instrument. A report is being prepared describing the measurement program and the aerosol size distributions.

PLANS FOR FY 82:

1. Obtain further aerosol measurements with the Langley FSSP on the Ames 990 aircraft from October 12 - November 20, 1981 in conjunction with the MSFC Beta Measurement Program as well as on other available 990 flights.

2. Perform a laboratory intercomparison with standard reference particles between the MSFC Beta System and the FSSP probe.

3. Attempt to correlate airborne aerosol measurements obtained by the FSSP and the Beta probes based on the laboratory intercomparisons.

RECOMMENDATIONS FOR NEW RESEARCH:

1. Equip the Convair 990 aircraft with a filter or impactor device to collect aerosol samples for morphological and chemical analysis.

2. Obtain comprehensive aerosol information using the FSSP and the aerosol collector in selected seasonal and geographical locations, including remote maritime regions.

TITLE: Airborne Doppler Lidar Project

Research Investigator: J. W. Bilbro
Optics Branch, EC32
Marshall Space Flight Center
MSFC, AL 35812
(205) 453-3941
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Significant FY '81 Accomplishments:

1. Modification of the Doppler Lidar System was completed and integrated into the Ames Research Center CV-990.

2. Calibration of the instrument on board the CV-990 was accomplished.

3. Eighty one hours were flown aboard the CV-990 in support of instrument checkout and scientific investigations.

4. The Doppler Lidar was removed from the CV-990, installed in its trailer and returned to MSFC to prepare for ground based testing.

Current Focus of Research Work:

Effort is presently being expended on the analysis of data collected in order to determine system accuracy and efficiency.

Plans for FY '82:

1. The Doppler Lidar will be operated as a ground based system.

2. Refurbishment of some of the system electronics will be performed.

3. Detailed planning for the FY '82 flight series will be done.

4. A second series of flight tests will be performed.

Recommendations For New Research:

Investigations into isotopic CO_2 wavelengths should be pressed in order to improve range capability.

Publications:

Fichtl, George H.; Bilbro, James W.; Kaufman, John W. "MSFC Doppler Lidar Science Experiments and Operations And Operations Plans For 1981 Airborne Test Flight." (MSFC internal note)

Krause, M., DiMarzio, C., Buck, C., Wiley, G., Bilbro, J., Fichtl, G., Shaw, K., Lee, R. "Airborne Doppler Lidar Severe Storms Measurement System," Coherent Laser Radar for Atmospheric Sensing; Aspen, CO, July 1980.

Bilbro, J. W., Johnson, S. C., Jones, W. D., Riddle, A. N., Gorzynski, E. J., Lee, R. W.; "Doppler Lidar Signal Processor Comparison Measurements," Coherent Laser Radar For Atmospheric Sensing; Aspen, CO, July 1980.

TITLE: Severe Storms Doppler Lidar Signal Processing

RESEARCH INVESTIGATOR: R. W. Lee
Lassen Research
Manton, CA 96059
(916) 474-3966

FY-81 ACCOMPLISHMENTS:

In addition to providing the Doppler processor for the severe-storms airborne lidar system, a series of algorithms for windfield retrieval was defined and tested. These algorithms were developed with three objectives in mind: 1) to produce vector flow fields on any desired grid system; 2) to minimize the impact of instrumental deficiencies (low signal-to-noise ratio, missing measurements, clutter) upon the accuracy, continuity, and resolution of the measurements; 3) to estimate the probable error in the flow, divergence, and vorticity fields through use of internal and a priori information.

These objectives were met through the use of an adaptive least-squares surface fitting algorithm. The two independent scalar fields (forward and aft radial velocity fields) are first edited by an algorithm which establishes measurement weights, and then fitted to quadratic surfaces. The degree of smoothing obtained is the minimum amount consistent with the quality of the measurements in each region.

PLANS FOR FY-82:

The windfield retrieval algorithms will be optimized to match the characteristics of the data obtained in the 1981 flight program. A study of the error sources in this data will be conducted: where possible, the effects of these errors will be minimized; recommendations regarding improvement of aircraft instrumentation may be made.

RECOMMENDATIONS FOR NEW RESEARCH:

The adaptive techniques used for windfield retrieval can be extended to the recognition and quantification of convective structures and other coherent features present in the windfields.

PUBLICATIONS PREPARED IN FY-81:

Processing of 2-dimensional lidar-derived windfields, 20th Conf. on Radar Meteorology, American Meteorological Society, Boston, Dec. 1981.

Title: Preliminary Assessment of 1981 Airborne Doppler Lidar Measurements

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Significant Accomplishments FY81:

During the past reporting period the airborne test flights of the MSFC Doppler Lidar System (DLS) were successfully accomplished. These flight tests consisted of a series of

experiments aimed at 1) engineering check-out of the DLS and 2) acquisition of detailed wind field data aimed at the study of severe storms and local weather phenomena. The flight tests involved approximately 60 hours of flight of the DLS aboard the NASA Convair 990 over a one and one-half month period from mid-June to the end of July 1981. Flight tests were performed in three regions of the United States - California, Oklahoma, and Montana and neighboring states.

The California tests involved 1) flights by the Walnut Grove, 1500 ft TV tower for intercomparison studies of wind measured via the DLS and standard anemometers located on the tower, 2) flights in and on the western side of the San Gorgonio Pass to measure local effects associated with air flow through the Pass, and 3) flights around the periphery of the California Central Valley to assess the nature of flow into the Central Valley via the Cortinas Straits. The Walnut Grove anemometer/DLS comparison flights were the first flights of the DLS after the initial engineering check-out flight, and the results of these flights were intended to provide decision information relative to whether or not the project should proceed with scientific tests in California, Oklahoma, and Montana. It turned out that the Walnut Grove tests were successful. The San Gorgonio test flights involved two flights of the CV-990 in and on the western side of the San Gorgonio Pass with supportive wind observations acquired by California Edison Power Company. The Central Valley test flights involved two flights of the CV-990 around the Central Valley with special emphasis on 1) the flow through the Cortinas Straits to estimate two-dimensional flow divergence and 2) the flow at the southern and northern extremities of the Central Valley.

The Oklahoma flight tests consisted of four flights. These tests involved 1) flights to acquire DLS data in conjunction with Doppler radar data acquired with the NOAA/NSSL Doppler radar for intercomparison studies, and 2) acquisition of data on atmospheric boundary layer flows, thunderstorm gust fronts, cloud entrainment processes, and flows associated with heat island effects.

The Montana flight tests consisted of five flights with the Cooperative Convective Precipitation Experiment (CCOPE). These tests involved flights to acquire detailed data sets on 1) convective boundary layers, 2) thunderstorm cold air outflows, 3) anvil cloud flows, and 4) flows about turret clouds. These tests are particularly of interest because supportive data was acquired with CCOPE 1) aircraft (Queen Air and Sabreliner), 2) surface observation network (PROBE), 3) radar network

(Doppler and intensity returns) and 4) rawinsonde network. In the two boundary layer flight tests the CCOPE project released chaff prior to the CV-990 flight tests to insure Doppler radar returns would be acquired. Furthermore, in situ measurements of wind were acquired by the NCAR Queen Air and Sabreliner with gust probes in the field of view of the DLS approximately two miles from the CV-990.

The 1981 DLS flight tests were successful in as much as 1) essentially all scientific data acquisition plans were accomplished 2) the DLS performed exceptionally well with very little lost data acquisition time due to instrument malfunctions.

Current Focus of Research Work:

We are currently processing the DLS data for preparation of data sets for use by members of the atmospheric science community.

Plans for FY82:

During 1982 we will 1) analyze the data acquired during the 1981 flight program, 2) plan and execute (if approved) a 1982 flight program, and 3) perform ground-based tests with the DLS at MSFC.

Recommendations for New Research:

The full potential of the DLS has not been exploited. Research utilizing scan modes other than now in use should be explored. The DLS can be programmed to do various kinds of scanning - in particular volume scanning. Volume scanning could be extremely useful in the study of small scale motions associated with severe storms and local weather phenomena, i.e. entrainment processes, gust fronts, boundary layers, etc. Downward looking Doppler lidar could also provide new insights into severe storms and boundary layer phenomena, i.e. entrainment at tops of clouds, etc.

APPENDIX

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NASA/MSFC FY-81
ATMOSPHERIC PROCESSES RESEARCH REVIEW
September 1, 2, and 3, 1981
Building 4723 Room 109
MARSHALL SPACE FLIGHT CENTER

Tuesday, September 1

8:30 WELCOME - CHARLES A. LUNDQUIST

8:40 INTRODUCTORY REMARKS - WILLIAM W. VAUGHAN, NASA/MSFC

8:50 UPPER ATMOSPHERE PROGRAM - ROBERT E. SMITH, CHAIRMAN, NASA/MSFC

8:55 Polyatomic Molecule Decomposition in the Stratosphere During a Geomagnetic Storm, KYO SEKIHARA, MSFC/NRC

9:15 Atmospheric Emissions Photometric Imager on Spacelab, GARY SWENSON, NASA/MSFC

9:35 COMMENTS - SHELBY TILFORD, NASA/OSTA

9:45 GLOBAL WEATHER - GEORGE H. FICHTL, CHAIRMAN; WILLIAM FOWLIS, CO-CHAIRMAN NASA/MSFC

9:50 *Overview of Global Weather Satellite Applications, GEORGE H. FICHTL, NASA/MSFC

10:10 Observed Structure of Global Phenomena from Satellite Data - Prospects for Prediction, JOHN DUTTON, PENN ST.

10:30 BREAK

10:50 Multi-Period Spectral Models of Global Phenomena, JOHN CLARK, PENN ST.

11:10 The Role of Latent Heat Release in Baroclinic Waves Without β Effect, CHUNG-MUH TANG, MSFC/USRA

11:30 The Influence of Latent Heat Release on Extratropical Cyclone Energetics, PHILIP SMITH, PURDUE

11:50 Latent Heat and Cyclonic Systems - A Case Study, JOHN CLARK, PENN ST.

12:10 LUNCH

1:20 *Overview of the AGCE Program, WILLIAM W. FOWLIS, NASA/MSFC

1:40 Hydrostatic Calculations of Axisymmetric Flow and Its Stability for the AGCE Model, ROBERT L. GALL, UNIVERSITY OF ARIZONA, and TIMOTHY L. MILLER, UNIVERSITY OF ARIZONA

2:00 Cylindrical Numerical Models: Basic States, FRED LESLIE, NASA/MSFC, and KENNETH KOPECKY, DRAKE UNIVERSITY

2:20 Spherical Numerical Models: Basic States and Stability, GLYN O. ROBERTS, MSFC/USRA

2:40 BREAK

3:00 The Three Dimensional, Numerical Model for the AGCE, GLYN O. ROBERTS, MSFC/USRA

3:20 Linear and Nonlinear Spin Up - Numerical Model Validation Studies, JAE M. HYUN, MSFC/USRA

3:40 Theoretical Studies of Baroclinic Flows, BASIL N. ANTAR, UTSI

4:00 Flow Regime Studies with a Simplified General Circulation Model, JOHN E. GEISLER, UNIVERSITY OF MIAMI, ERIC J. PITCHER, UNIVERSITY OF MIAMI

4:20 The AGCE Instrument Feasibility Study, WILLIAM FOWLIS, NASA/MSFC

4:40 COMMENTS - JOHN THEON, NASA/OSTA

5:00 (Option) McIDAS and MASS visit, Building 4481, Rooms 417 and 435.

Wednesday, September 2

8:30 INTRODUCTORY REMARKS - WILLIAM W. VAUGHAN, NASA/MSFC

8:40 *Overview of GFFC Instrument Development and Spacelab 3 Mission Activities, GEORGE H. FICHTL, NASA/MSFC

9:00 Studies of Planetary and Solar Convection for Spacelab 3/GFFC, JOHN HART, UNIVERSITY OF COLORADO

SEVERE STORMS AND LOCAL WEATHER RESEARCH PROGRAM

ATMOSPHERIC ELECTRICITY - HUGH CHRISTIAN, CHAIRMAN; WAYNE WAGNON, CO-CHAIRMAN

9:20 *Overview of Atmospheric Electricity Program, HUGH CHRISTIAN, NASA/MSFC

9:50 NOSL, Space Shuttle Lightning Observation Experiment, B. VONNEGUT, SUNY (Presented by Robert Smith)

10:10 BREAK

10:20 Correlated Satellite and Ground Based Studies of Lightning, BRUCE EDGAR, AEROSPACE

10:50 U-2 Lightning Measurement Program: Sensor System Overview and Preliminary Results, TOM BARNES, NASA/MSFC

11:10 Airborne and Ground-Based Studies of Lightning Spectra, STU CLIFTON, NASA/MSFC

11:30 Spectrum of Lightning, RICHARD ORVILLE, SUNY

11:50 LUNCH

1:00 R. F. Lightning Studies at MSFC, WAYNE WAGNON, NASA/MSFC

1:20 Locations of Lightning Strikes in Severe Storms, RICHARD ORVILLE, SUNY

1:40 Studies of Hurricane Electrical Activity using R. F. Interferometric Techniques, RICHARD JOHNSON, SWRI

2:00 Long Range Detection of Lightning using ELF Techniques, WILLIAM TAYLOR, NOAA/NSSL

2:20 Severe Storm Electricity via Storm Intercept, ROY T. ARNOLD, UNIVERSITY of MISSISSIPPI

2:40 Severe Storm Electrical Activity, DAVE RUST, NOAA/NSSL

3:00 COMMENTS - JAMES DODGE, NASA/OSTA

3:05 BREAK

CLOUD PHYSICS - J. A. ANDERSON, CHAIRMAN; VERNON KELLER, CO-CHAIRMAN

3:20 Warm Cloud Development Studies, JEFF ANDERSON, NASA/MSFC

3:40 Cold Cloud Development Studies, VERNON KELLER, NASA/MSFC

4:00 Cloud Condensation-Aerosol Nucleation-Cloud Forming Experiments, WARREN KOCMOND, DRI

STORM-MESOSCALE/SATELLITE APPLICATIONS - GREGORY S. WILSON, CHAIRMAN, JAMES E. ARNOLD, CO-CHAIRMAN

4:20 *Overview of Mesoscale and Severe Storm/Satellite Applications, GREGORY WILSON, NASA/MSFC

4:30 MSFC's Correlative Ground-Truth System and Field Programs, JAMES ARNOLD, NASA/MSFC

5:15 VISIT TO ALABAMA SPACE AND ROCKET CENTER

7:00 Stand-up Buffet

8:00 VAS/CSIS, WILLIAM SMITH/PAUL MENZEL, NOAA/UNIVERSITY OF WISCONSIN

Thursday, September 3

8:30 INTRODUCTORY REMARKS - WILLIAM W. VAUGHAN, NASA/MSFC

8:40 Satellite-Infrared, Rawinsonde and Gravity Wave Study of Severe Convective Storms, R. J. HUNG, UAH

9:00 Acoustic and Gravity Waves in the Neutral Atmosphere and the Ionosphere Generated by Severe Storms, N. BALACHANDRAN, COLUMBIA UNIVERSITY

9:20 Analysis of Satellite Data for Sensor Improvement, T. THEODORE FUJITA, UNIVERSITY OF CHICAGO

9:40 Research Applications of MSFC's McIDAS and MASS Computer Systems, GARY JEDLOVEC, MSFC/USRA

10:00 Automated Cloud-Motion System, GREGORY S. WILSON, NASA/MSFC; ROBERT JAYROE, NASA/MSFC

10:20 BREAK

10:30 Applications of Satellite Data to Mesoscale Studies, DAVE SUCHMAN, UNIVERSITY OF WISCONSIN (Presented by Michael Goodman)

10:50 Diagnostic Analysis of the Severe Storm Environment, JAMES SCOGGINS, TEXAS A&M UNIVERSITY

11:10 Storm Environment Interactions Determined from AVE-SESAME and Satellite Data, HENRY FUELBERG, ST. LOUIS UNIVERSITY

11:30 LUNCH

12:40 Mesoscale Circulation and Convective Storm Formation, GREGORY S. WILSON, NASA/MSFC

1:00 Diagnostic and Satellite Derived Ageostrophic Circulation Related to Severe Storms, JAMES ARNOLD, NASA/MSFC

1:20 Diagnostic/Numerical Studies of Jet Structure and Storm Formation, DON JOHNSON, UNIVERSITY OF WISCONSIN

1:40 COMMENTS - JAMES C. DODGE, NASA/OSTA

DOPPLER LIDAR WINDS APPLICATIONS - GEORGE H. FICHTL, CHAIRMAN; JAMES BILBRO, CO-CHAIRMAN

1:50 *Overview of MSFC's Doppler Lidar Backscatter and Wind Sensor Research Activities, GEORGE H. FICHTL, NASA/MSFC

2:00 Backscatter Research for Remote Measurement of Wind from Space, WILLIAM D. JONES, NASA/MSFC

2:20 Preliminary Results of Airborne Aerosol Measurement Analysis and Recommended Rationale for Backscatter Data Acquisition for Satellite Sensor Detection, DAVID BOWDLE, MSFC/USRA

2:40 COMMENTS - JOHN THEON, NASA/OSTA

3:00 Airborne Doppler Lidar Wind Sensor Instrumentation Project, JAMES W. BILBRO, NASA/MSFC; M. C. KRAUSE, RAYTHEON; ROBERT W. LEE, LASSEN RESEARCH

3:50 Preliminary Assessment of 1981 Airborne Doppler Lidar Wind Measurements, GEORGE FICHTL, NASA/MSFC; RICHARD DOVIAK, NOAA/NSSL; WILLIAM CLIFF, BATTELLE; GEORGE D. EMMITT, MSFC/USRA; DAN FITZGERALD, NASA/MSFC; JAMES TELFORD, DRI.

4:50 COMMENTS - JAMES C. DODGE, NASA/OSTA

5:00 SUMMARY COMMENTS ON RESEARCH REVIEW, SHELBY TILFORD, NASA/OSTA

5:10 CONCLUDING REMARKS - WILLIAM W. VAUGHAN, NASA/MSFC

NOTE: Due to lack of time on the agenda, presentations were not possible on all in-house and sponsored research efforts. However, the overviews at the start of each activity will endeavor to incorporate pertinent remarks on those research efforts not included in the detail presentations. In addition, the report for the review will include most of those efforts not formally presented.

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16. ABSTRACT

A review of the NASA/MSFC FY-81 Atmospheric Processes Research Program was held in Huntsville, Alabama, September 1-3, 1981. The review covered research tasks sponsored by the NASA Office of Terrestrial and Space Applications, Atmospheric Processes Branch, in the areas of upper atmosphere, global weather, and severe storms and local weather. This report contains the research project summaries, in narrative outline form, supplied by the individual investigators together with the agenda and other information about the review.

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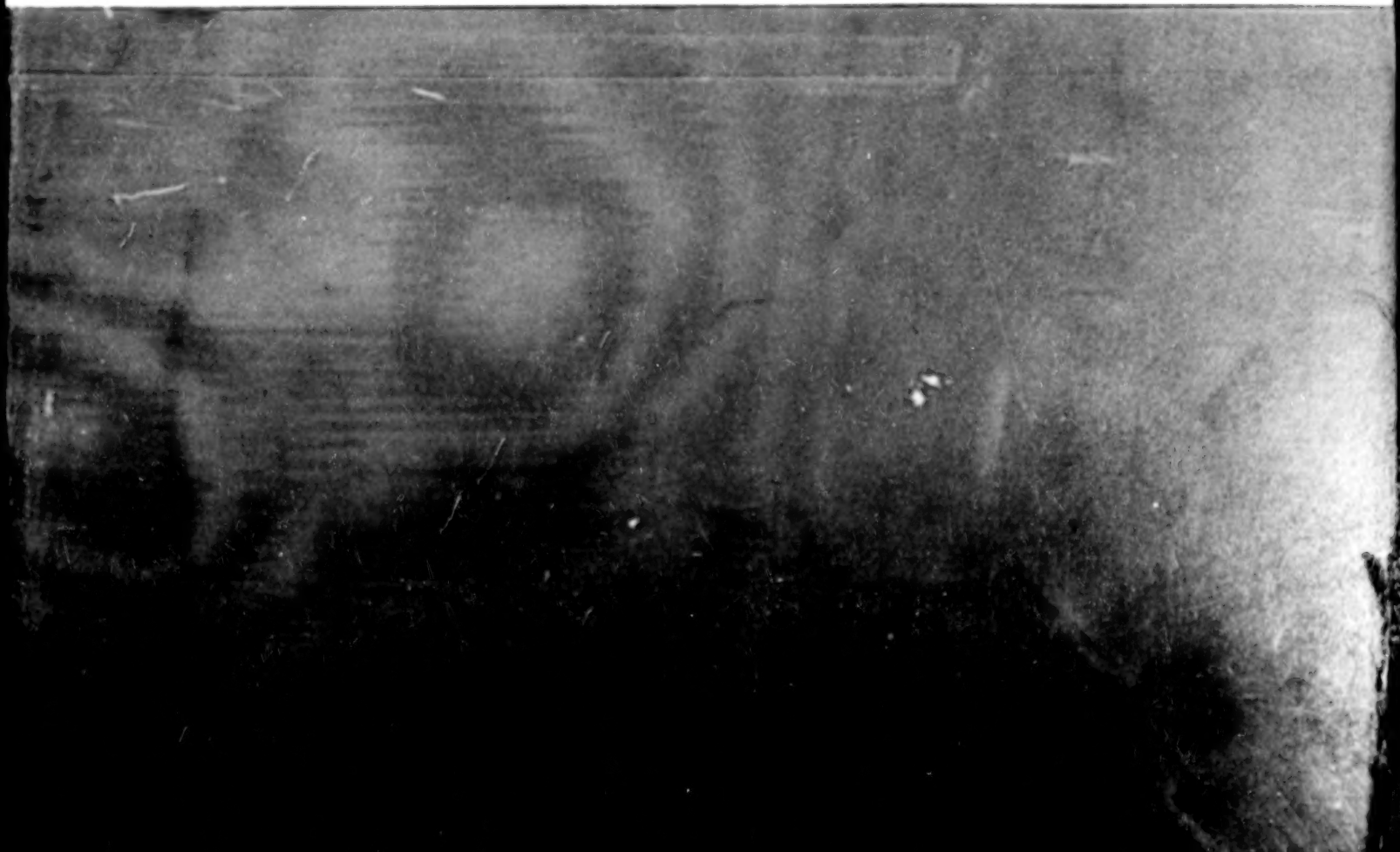
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